CHAPTER 5 – POST CONSTRUCTION STORMWATER MANAGEMENT

5.1 GENERAL

Land development projects and associated increases in impervious cover alter the hydrologic response of local watersheds and increase storm water runoff rates and volumes, flooding, stream channel erosion, and sediment transport and deposition; This storm water runoff contributes to increased quantities of water-borne pollutants, and; Storm water runoff, soil erosion, and nonpoint source pollution can be controlled and minimized through the regulation of storm water runoff from development sites. For these reasons, the Arkansas Department of Environmental Quality (ADEQ), under regulations administered by the United States Environmental Protection Agency (EPA) requires the City of Fort Smith to meet certain requirements as established in the National Pollutant Discharge Elimination System (NPDES), Phase II, for Small Municipal Separate Storm Sewer Systems (MS4's).

5.1.1 *Detention Required*

If hydrologic and hydraulic studies reveal that the post-development runoff for a proposed development or redevelopment project one acre or more in size will exceed the pre-development runoff, and the existing drainage system is not adequate to carry the post-development runoff, then the proposed development or redevelopment project shall not be permitted unless one or more of the following mitigation measures are used: onsite detention, offsite or regional detention, or improvements to the existing drainage system.

All detention facilities shall be designed to limit the peak storm water discharge rate of the 10-, 25-, 50-, and 100-year storm frequencies after development to pre-development flow rates.

5.1.1.1 Acceptable Detention Practices

Only stormwater ponds and wetlands shall be allowed for publicly owned detention, i.e. within residential subdivisions and developments (see Section 5.9). Other methods of detention such as infiltration trenches, infiltration basin, etc., will not be allowed for publicly owned detention and are discouraged for privately owned detention. If other methods are proposed, proper documentation of soil data, percolation, geological features, etc., will be needed for review and consideration.

5.1.1.2 Parking Lot Detention

Privately owned detention is permitted in parking lots to maximum depths of 6 inches. In no case shall the maximum limits of ponding be designed closer than 10 feet from a structure unless waterproofing of the structure and pedestrian accessibility are properly documented and approved. The minimum freeboard and the maximum ponding elevation to the lowest sill or floor elevation shall be 2 feet.

5.1.2 *Stormwater Treatment Required*

Development and redevelopment projects one or more acres in size (or less than an acre if part of a larger common plan of development), that will increase the impervious area onsite, shall not be permitted without employing Stormwater Treatment Practices (STP's) to address the water quality of the surface waters being discharged from the site. All STP's or systems of STP's utilized to address water quality shall be required to capture and treat the Water Quality Volume (WQ_v). The WQ_v shall be equal to:

$$WQ_v = (P_I)(R_v)(A)/12 \tag{5.1}$$

Where:
WQ_v = Water Quality Volume (acre-ft)
P_I = The First One Inch (1.0") of Direct Runoff
R_v = Runoff Coefficient
A = Site Area (acres)

$$R_v = 0.05+0.009I \tag{5.2}$$

Where:
I = Site Impervious Cover (%)

The WQ_v shall be based on the impervious cover of the proposed site. Offsite existing impervious areas may be excluded from the calculation of the water quality volume requirements.

5.1.2.1 Acceptable Stormwater Treatment Practices (STPs)

All acceptable STP's shall be designed to capture and treat the WQ_v with a goal of at least 80% removal of total suspended solids (TSS) from post-construction discharges (See Table 5.2 for Pollutant Removal Percentages). STP's that meet these requirements can be divided into five basic groups – Stormwater Ponds, Wetlands, Infiltration Systems, Filtering Systems, and Open Channel Systems. When properly designed, the following STP's shall be considered sufficient to meet the requirements above:

Group 1: Stormwater Ponds

Stormwater ponds are practices that have a combination of a permanent pool, extended detention or shallow marsh equivalent to the entire WQ_v. Design variants include:

- Micropool Extended Detention Pond
- Wet Pond
- Wet Extended Detention Pond
- Multiple Pond System
- "Pocket" Pond

Group 2: Wetlands

Stormwater wetlands are practices that create shallow marsh areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v. Design variants include:

- Shallow Wetland
- ED Shallow Wetland
- Pond/Wetland System
- "Pocket" Wetland

Group 3: Infiltration Systems

Stormwater infiltration practices capture and temporarily store the WQ_v before allowing it to infiltrate into the soil. Design variants include:

- Infiltration Trench
- Infiltration Basin

Group 4: Filtering Systems

Stormwater filtering system capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include:

- Surface Sand Filter
- Underground Sand Filter
- Perimeter Sand Filter
- Organic Filter
- Bioretention

Group 5: Open Channel Systems

Open channel systems are vegetated open channels that are explicitly designed to capture and treat the full WQ_v within dry or wet cells formed by checkdams or other means. Design variants include:

- Dry Swale
- Wet Swale
- Grass Channels

5.1.2.2 Sub-Standard Storm Water Treatment Practices

Many current and future stormwater management structures may not meet the performance criteria specified in Section 5.1.2.1 above to qualify to be used as "stand-alone" practices for full

WQ_v treatment. Reasons for this include poor longevity, poor performance, inability to decrease TSS by 80%, or inadequate testing. Some of these practices include:

- Dry Extended Detention Ponds
- Catch Basin Inserts
- Water Quality Inlets and Oil/Grit Separators
- Hydro-Dynamic Structures
- Filter Strips
- Deep Sump Catch Basins
- Dry Wells
- On-Line Storage in the Storm Drain Network

In some cases, these practices are appropriately used for pretreatment, as part of an overall STP system, or may be applied in redevelopment situations on a case-by-case basis where other practices are not feasible. New structural BMP designs are continually being developed, including many proprietary designs. All current and future structural practice design variants should fit in one of the five STP groups referenced above if the intent is to use them independently to treat the full WQ_v. Current or new STP design variants cannot be accepted for inclusion on the list until independent pollutant removal performance and monitoring data determine that they can meet the 80% TSS removal target and that the new STPs conform with local and/or State criteria for treatment, maintenance, and environmental impact.

5.1.2.3 Stormwater Hot Spots

Stormwater hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater. A greater level of stormwater treatment is needed at hot spot sites to prevent pollutant washoff after construction. This typically involves preparing and implementing a ***stormwater pollution prevention plan*** (SWPPP) that involves a series of operational practices at the site that reduces the generation of pollutants by preventing contact with rainfall.

For the purposes of this document, stormwater hot spots shall be classified as industrial facilities that:

- have Standard Industrial Classification (SIC) codes listed in "40 CFR 122.26(b)(14) Subpart (i) – (xi)"
- and, are required to submit applications for a storm water permit to the Arkansas Department of Environmental Quality (ADEQ).

A copy of "40 CFR 122.26(b)(14) Subpart (i) – (xi)" can be found in Appendix 5A.

5.1.3 *Variances*

Criteria for differential runoff and detention guidelines are set out in the following in an attempt to decrease the possible effects of development on downstream properties due to increased runoff and pollutants. Variances to the requirements in this chapter may be granted by the Engineering Department if it is determined that detention would be ineffective to prevent flooding or would aggravate the flooding conditions. Variances to the detention requirements do not relieve the developer/owner of any water quality requirements. However, reductions in the required WQ_v are possible with the use of storm water credits (See Section 5.9).

5.1.4 *Verification of Adequacy*

Projects shall provide documented verification of adequacy according to the scope and complexity of design. Documentation must have original signature and be certified as-built by the same Arkansas Registered Professional Engineer, if feasible.

5.2 DESIGN CRITERIA – STORMWATER PONDS

Stormwater ponds are practices that have a combination of a permanent pool, extended detention or shallow marsh equivalent to the entire WQ_v. Design variants include:

- Micropool Extended Detention Pond (Figure 5-1)
- Wet Pond (Figure 5-2)
- Wet Extended Detention Pond (Figure 5-3)
- Multiple Pond System (Figure 5-4)
- "Pocket" Pond (Figure 5-5)

The term "pocket" refers to a pond or wetland that has such a small contributing drainage area that little or no baseflow is available to sustain water elevations during dry weather. Instead, water elevations are heavily influenced and, in some cases, maintained by a locally high water table.

Stormwater ponds may be used in residential, private, commercial, and industrial subdivisions and developments to meet the detention and WQ_v requirements.

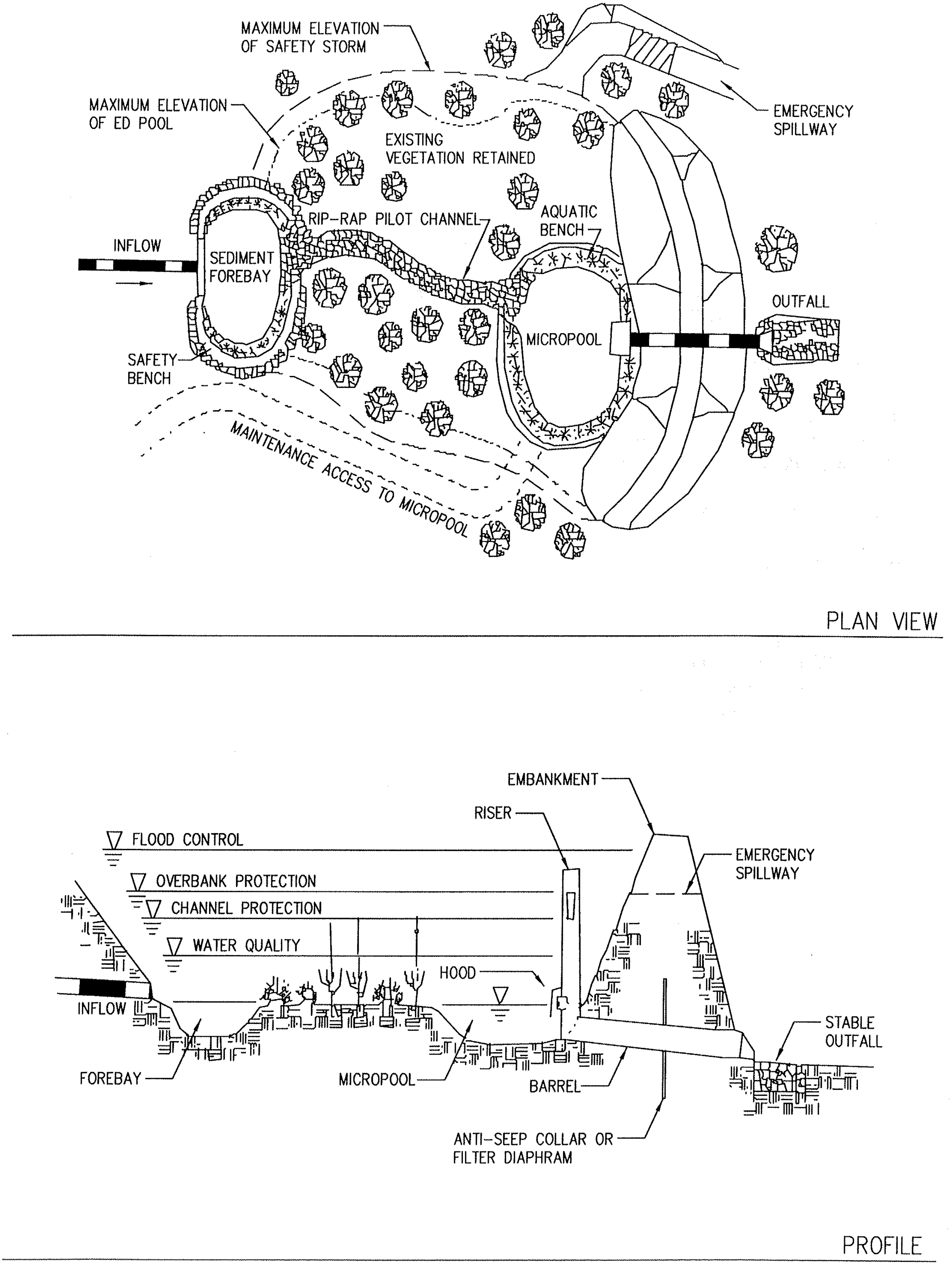
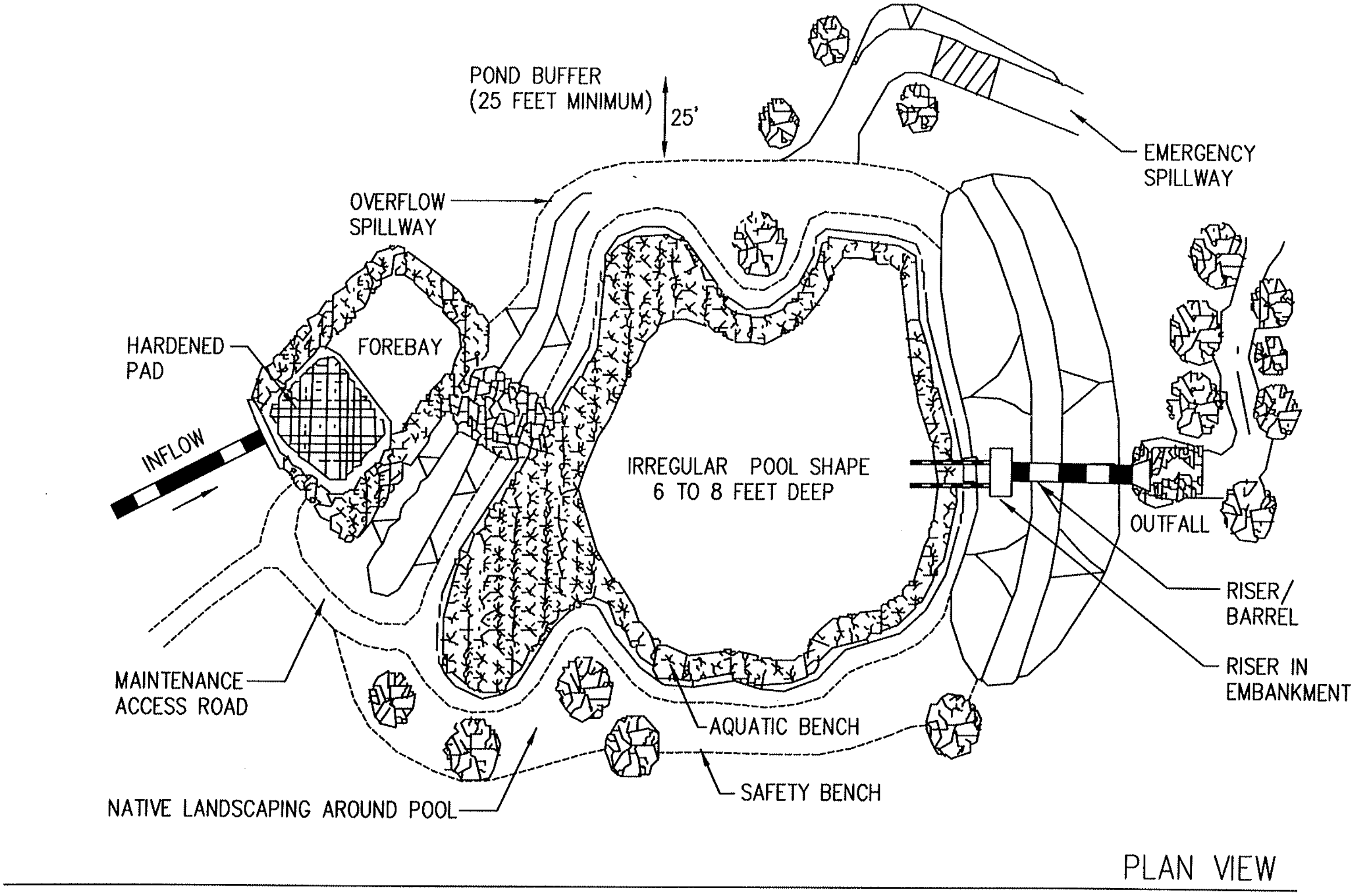


FIGURE 5-1. Micropool Extended Detention Pond



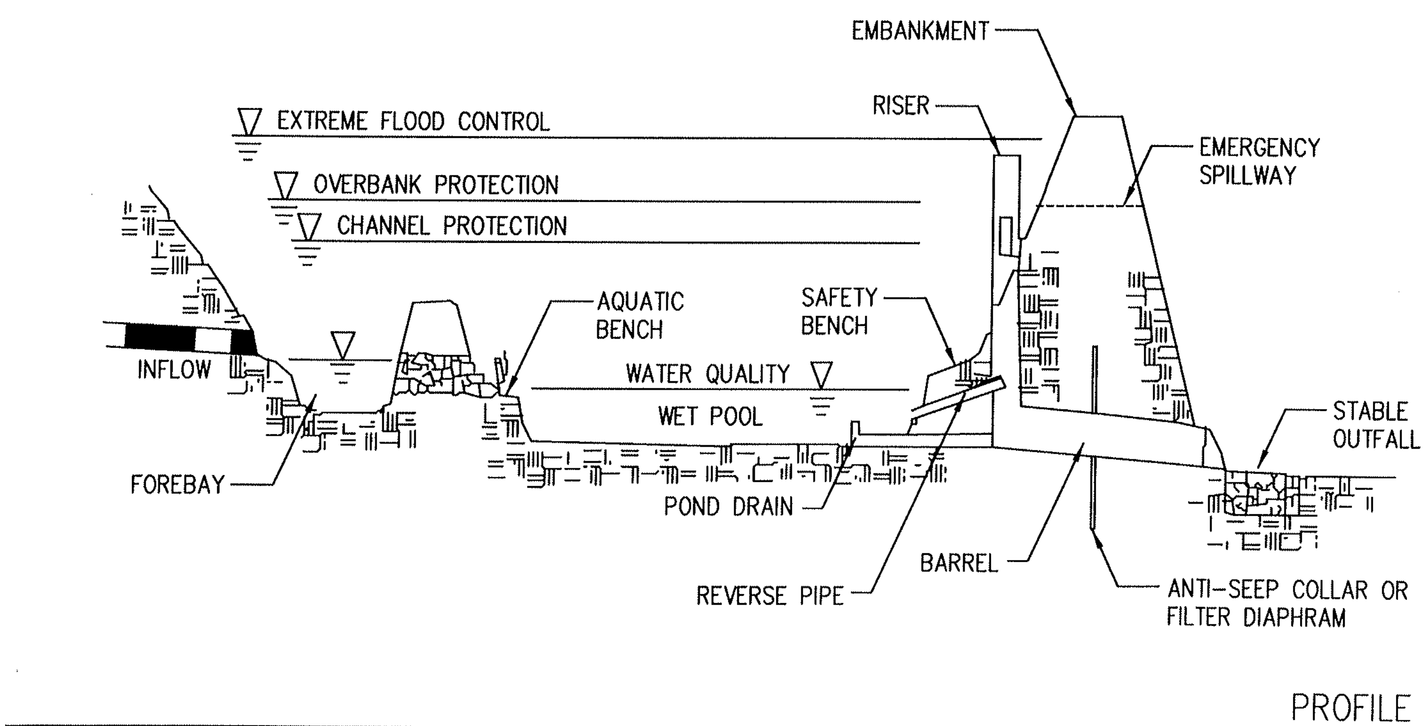


FIGURE 5-1. Micropool Extended Detention Pond

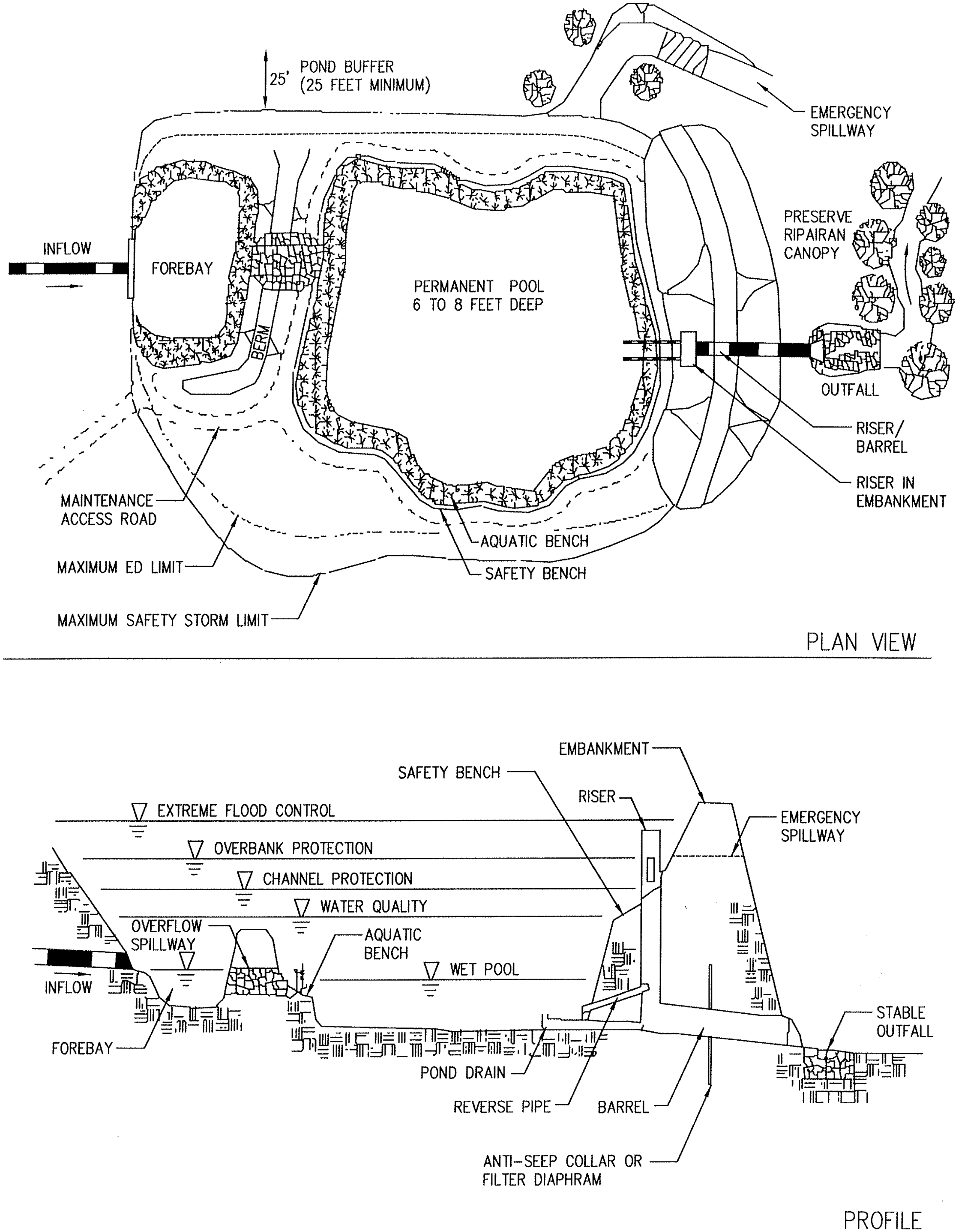
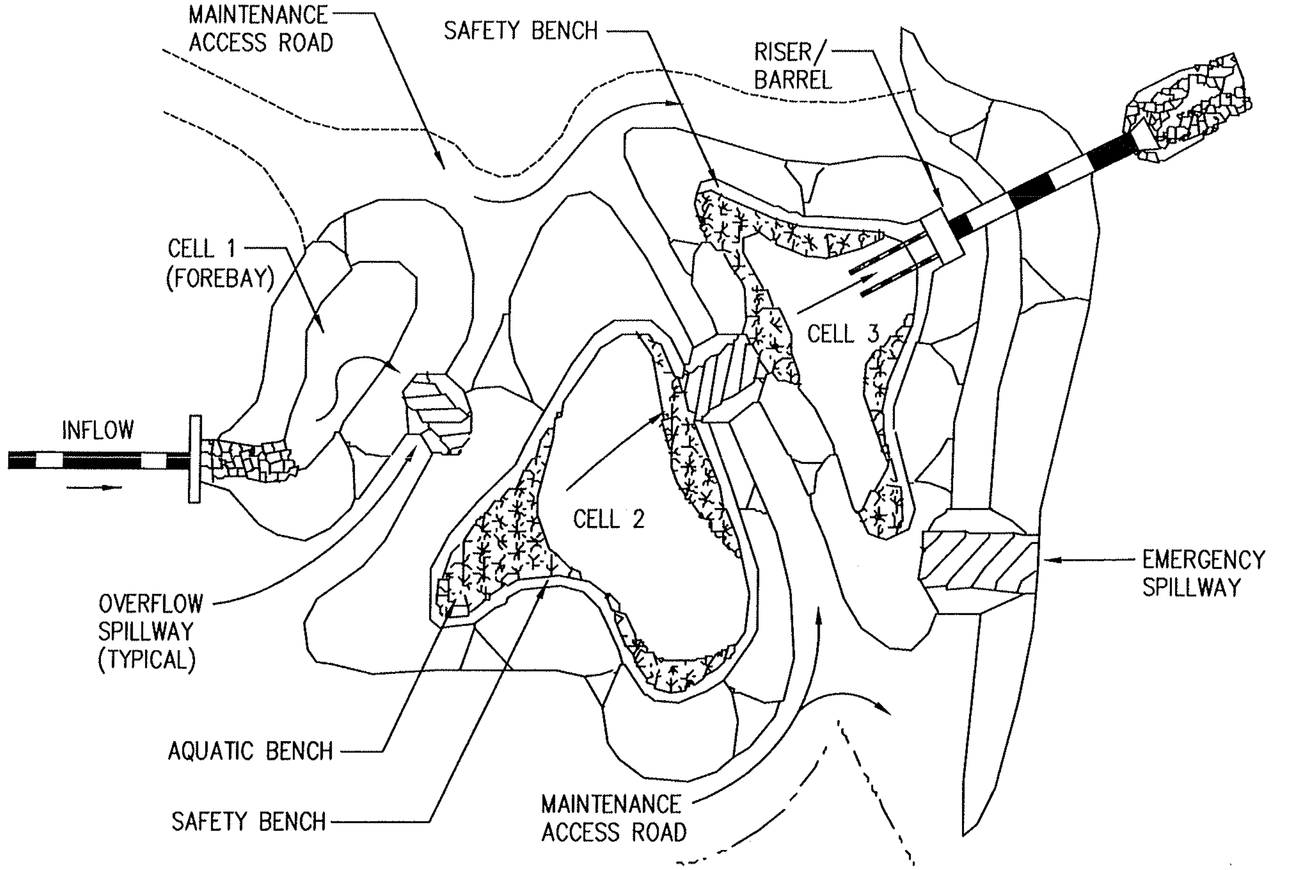
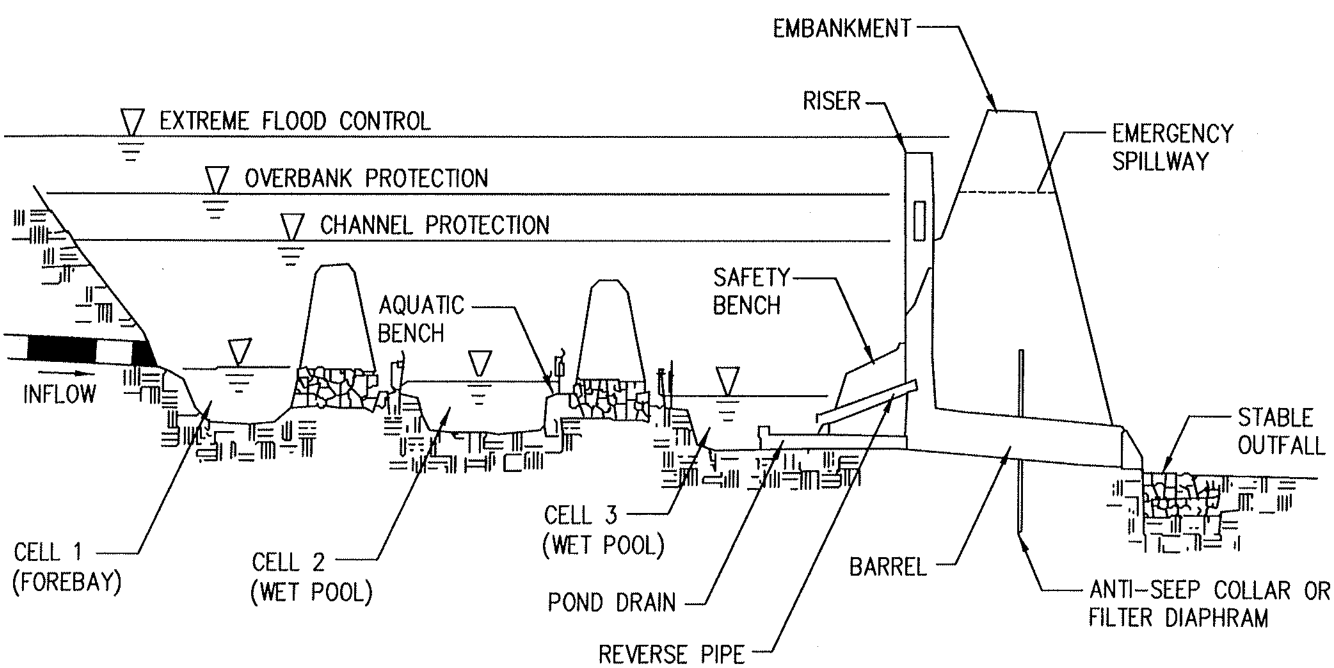


FIGURE 5-3. Wet Extended Detention Pond



PLAN VIEW



PROFILE

FIGURE 5-4. Multiple Pond System

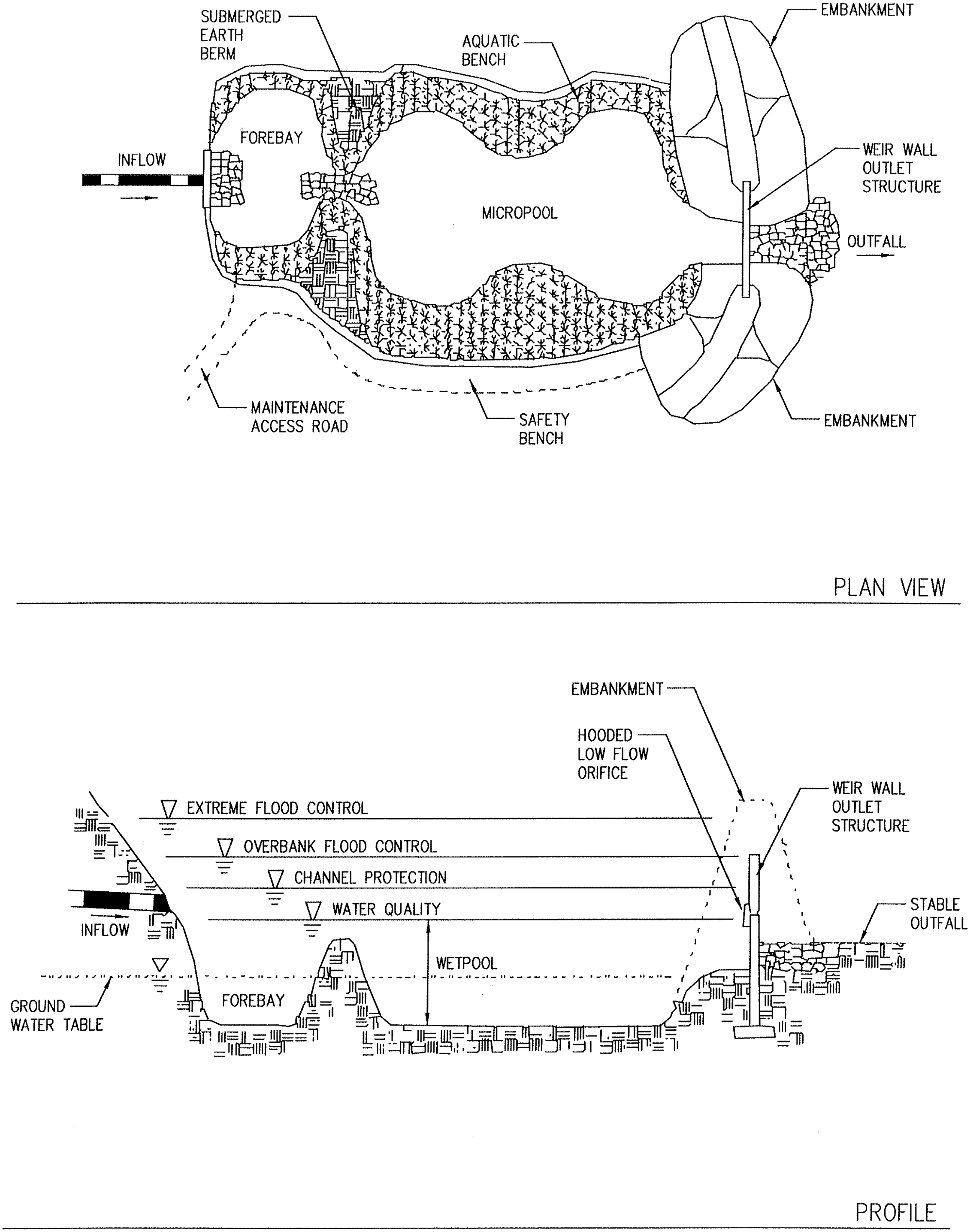


FIGURE 5-5. Pocket Pond

Dry extended detention ponds that have no permanent pool are not considered an acceptable "stand-alone" option for meeting WQ_v. However, with the approval of the Engineering Department, they may be used in conjunction with other STP's to meet the WQ_v requirement. They may also be used to meet the detention requirement.

5.2.1 *Feasibility Criteria*

When used to meet water quality requirements, a minimum contributing drainage area of ten acres or more is preferred for stormwater ponds, unless groundwater can be confirmed as the primary water source (i.e., pocket ponds).

Stormwater ponds shall not be located within jurisdictional waters, including wetlands.

Stormwater ponds shall be located within the parcel limits of the project under consideration, except as specified below. No stormwater ponds will be permitted within public road rights-of-way. Location of stormwater ponds immediately upstream or downstream of the project will be considered by special request if proper documentation is submitted with reference to practicality, feasibility, and proof of ownership or right-of-way use of the area proposed.

In no case shall the limits of maximum ponding for a stormwater pond be closer than 25 feet horizontally from any structure.

5.2.1.1 Safe Dam Act

National responsibility for the promotion and coordination of dam safety lies with FEMA. State responsibility for administration of the provisions of the Federal Dam Safety Act is given by Title 15, Chapter 22 of the Arkansas State Code. Rules and regulations relating to applicable dams are promulgated by the Arkansas Soil and Water Conservation Commission (ASWCC).

All dams within the state of Arkansas, except those that meet certain exemptions, must have a construction and operation permit from ASWCC. Under the ASWCC criteria, a dam is exempt from the regulations if it is less than 25 ft in height or has a normal storage volume less than 50 ac•ft. The ASWCC also allows an exemption if the crest height of the dam is below the ordinary high water mark of the stream at that location. However, smaller dams may also be required to meet the dam safety regulations as well. If persons downstream feel that their life or their property is endangered by a dam, they can petition the ASWCC for the dam safety regulations to be enforced *(2)*. Consult Reference *(2)* for more information on dam safety regulations, design criteria, and hazard classifications. Any questions regarding permits, exemptions, design criteria, or compliance with dam safety regulations should be directed to the ASWCC.

Dams which are greater than 10 feet in height but do not fall into State or Federal requirement categories shall be designed in accordance with the latest edition of the SCS Technical Release No. 60, "Earth Dams and Reservoirs," as Class "C" structures *(1), (8)*.

An analysis shall be furnished of any soil proposed for use in earthen dam construction. Borings of the foundation for an earthen dam may be requested by the Engineering Department. Earthen dam structures, of any height, shall be designed by a Professional Engineer registered to practice in the state of Arkansas.

5.2.1.2 Freeboard Criteria

All stormwater ponds shall have a minimum freeboard of one foot.

5.2.1.3 Minimum Geometric Criteria

The minimum length to width ratio for stormwater ponds is 1.5:1 (i.e., length relative to width). Long flow paths and irregular shapes are recommended.

5.2.1.4 Pond Benches

The perimeter of all deep pool areas (four feet or greater in depth) shall be surrounded by two benches:

- A safety bench that extends 15 feet outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench shall be 6%.
- An aquatic bench that extends up to 15 feet inward from the normal shoreline and has a maximum depth of eighteen inches below the normal pool water surface elevation.

5.2.1.5 Safety Features

Side slopes to the pond shall not exceed 3:1 (h:v), and shall terminate on a safety bench. Both the safety bench and the aquatic bench may be landscaped to prevent access to the pool. The bench requirement may be waived if slopes are 4:1 or flatter.

The principal spillway opening shall not permit access by small children, and endwalls above pipe outfalls greater than 24 inches in diameter shall be fenced to prevent a hazard.

5.2.2 *Detention Criteria*

When used to meet detention requirements, stormwater ponds shall be designed to limit the peak storm water discharge rate of the 10-, 25-, 50-, and 100-year storm frequencies after development to pre-development flow rates.

5.2.2.1 Volume of Detention

Volumes of detention shall be evaluated according to the following methods:

- Volumes of stormwater ponds with total drainage areas of 20 acres or less may be evaluated by the "Modified Rational Hydrograph Method."

- For basins with total drainage areas larger than 20 acres, the Owner's Engineer shall submit the proposed method of evaluation for the sizing of the stormwater pond to the Engineering Department. The method will be evaluated for professional acceptance, applicability, and reliability by the Engineering Department. No detailed review for projects larger than 20 acres will be rendered before the method of evaluation of the detention/retention basin is approved.

- The computed hydraulic detention volume shall be increased by 25 percent as a factor of safety and to provide for sediment storage. The Engineering Department may reduce this requirement depending on the development characteristics and stream stability of upstream tributary areas.

5.2.2.2 Routing Method

The hydrograph routing method used shall be the Modified Puls Method.

5.2.2.3 Stormwater Pond Design Procedure (Modified Rational Method)

1. Compute pre-development and post-development site characteristics:

- Drainage Area
- Composite Runoff Coefficient
- Time of Concentration

2. Determine rainfall intensity for pre-development conditions (10- through 100-year storm).

3. Compute pre-development peak runoff rates using Rational Formula. These flow rates will be the maximum allowable release rates from the detention basin.

4. Determine inflow hydrograph using Modified Rational Method (see example problem and Figure 5-6 in section 5.2.2.4).

5. Find estimated detention volume using Modified Rational Method

6. Size Stormwater Pond based on estimated required volume. Develop stage-storage curve for the detention basin.

7. Size release structure based on allowable release flow. Develop stage-discharge curve for the release structure.

8. Route the inflow hydrographs (developed using the Modified Rational Method for the 10- through 100-year storms) through the stormwater pond using Modified Puls Method.

9. Check routed hydrographs to ensure flows do not exceed pre-development peaks. Adjust stormwater pond and release structure if necessary.

5.2.2.4 Example Problem – Modified Rational Method

The following example problem describes the general procedure to complete a design of a stormwater pond using the Modified Rational Method. The values and information provided in this example do not represent actual data for the City of Fort Smith but are only provided to illustrate the procedure.

Given: A 10-acre site currently agricultural use is to be developed for townhouses. The entire area is the drainage area of the proposed stormwater pond.

Determine: Maximum release rate and required detention storage.

Solution:

Step 1: Determine 100-year peak runoff rate prior to site development. This is the maximum release rate from site after development.

NOTE: Where a stormwater pond is being designed to provide detention for both its drainage area and a bypass area, the maximum release rate is equal to the peak runoff rate prior to site development for the total of the areas minus the peak runoff rate after development for the bypass area. This rate for the bypass area will vary with the duration being considered.

Present Conditions $Q = CiA$ (See Section 2.4.1) (5.9)

$C = 0.30$
$T_c = 20$ minutes
$i_{100} = 7.0$ in./hr
$Q_{100} = 0.30(7.0)(10) = 21.0$ cfs (Maximum Release Rate)

Step 2: Determine inflow hydrograph for storms of various durations in order to determine maximum volume required with release rate determined in Step 1.

NOTE: Incrementally increase durations by 10 minutes to determine maximum required volume. The duration with a peak inflow less than the maximum release rate or where required storage is less than storage for the prior duration is the last increment.

Future Conditions (Townhouses)

$C = 0.80$
$T_c = 15$ minutes
$i_{100} = 7.7$ in./hr
$Q_{100} = 0.80(7.7)(10) = 61.6$ cfs

Check various duration storms.

20 min	$i = 7.0$	$Q_{in} = 0.80\ (7.0)\ (10) = 56.0$ cfs
30 min	$i = 5.8$	$Q_{in} = 0.80\ (5.8)\ (10) = 46.4$ cfs
40 min	$i = 5.0$	$Q_{in} = 0.80\ (5.0)\ (10) = 40.0$ cfs
50 min	$i = 4.4$	$Q_{in} = 0.80\ (4.4)\ (10) = 35.2$ cfs
60 min	$i = 4.0$	$Q_{in} = 0.80\ (4.0)\ (10) = 32.0$ cfs
70 min	$i = 3.7$	$Q_{in} = 0.80\ (3.7)\ (10) = 29.6$ cfs
80 min	$i = 3.4$	$Q_{in} = 0.80\ (3.4)\ (10) = 27.2$ cfs
90 min	$i = 3.1$	$Q_{in} = 0.80\ (3.1)\ (10) = 24.8$ cfs

The Maximum Storage Volume in cubic feet (cf) is determined by deducting the volume of runoff released during the time of inflow from the total outflow for each storm duration.

$$V = (time\ x\ Q_{in}\ x\ 60\ s/min) - (0.5\ x\ \ (time + T_c)\ x\ Q_{out}\ x\ 60\ s/min) \qquad (5.10)$$

15 min Storm Inflow 15 (61.6) (60) = 55,440 cf
Outflow 0.5 (30)(21.0)(60) = 18,900 cf

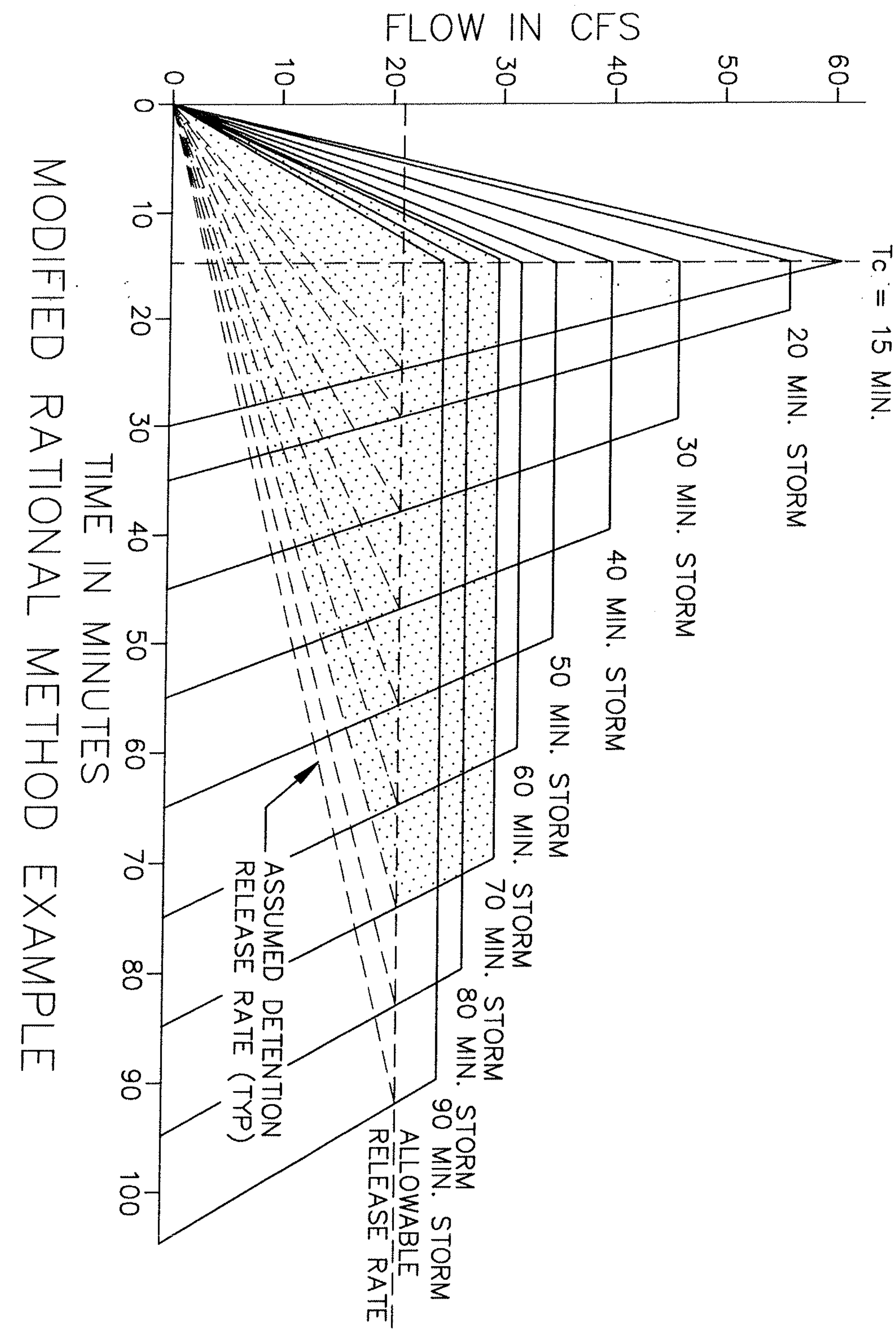
20 min Storm Inflow 20 (56.0) (60) = 67,200 cf
Outflow 0.5 (35)(21.0)(60) = 22,050 cf
Storage 45,150 cf

30 min Storm Inflow 30 (46.4) (60) = 83,520 cf
Outflow 0.5 (45)(21.0)(60) = 28,350 cf
Storage 55,170 cf

40 min Storm Inflow 40 (40.0) (60) = 96,000 cf
Outflow 0.5 (55)(21.0)(60) = 34,650 cf
Storage 61,350 cf

50 min Storm Inflow 50 (35.2) (60) = 105,600 cf
Outflow 0.5 (65)(21.0)(60) = 40,950 cf
Storage 64,650 cf

FIGURE 5-6. Example Problem, Modified Rational Method.



CONCEPT OF DETENTION POND MODIFIED RATIONAL METHOD EXAMPLE STANDARD DETAIL CITY OF FORT SMITH, ARKANSAS	The City of Fort Smith ARKANSAS	Project: Date: FEN. 2008 Scale: NONE Drawn By: RBR

60 min Storm Inflow 60 (32.0) (60) = 115,200 cf
Outflow 0.5 (75)(21.0)(60) = 47,250 cf
Storage 67,950 cf

70 min Storm Inflow 70 (29.6) (60) = 124,320 cf
Outflow 0.5 (85)(21.0)(60) = 53,550 cf
Storage 70,770 cf

80 min Storm Inflow 80 (27.2) (60) = 130,560 cf
Outflow 0.5 (95)(21.0)(60) = 59,850 cf
Storage 70,710 cf

90 min Storm Inflow 90 (24.8) (60) = 133,920 cf
Outflow 0.5 (105)(21.0)(60) = 66,150 cf
Storage 67,770 cf

Step 3: Route design storm hydrograph through the stormwater pond using the Modified Puls Routing Method or another approved method, based on final stormwater pond and release structure design. Computer programs to accomplish this are readily available.

5.2.2.5 Stormwater Detention Analysis Software

The City will allow the use of the following software or an acceptable equal approved by the Engineering Department for the analysis of storm water detention facilities: HEC-HMS, HEC-1, PondPack.

5.2.3 *Outlet Works*

Stormwater ponds shall be provided with effective outlet works. Safety considerations shall be an integral part of the design of all outlet works. Plan view and sections of the structure with adequate details shall be included in the plans.

The riser structure selected shall have documented evidence that it will control the 10-, 25-, 50-, and 100-year storm events. Generally, the full range of frequency control is achieved by selecting the 100-year and an intermediate frequency, such as the 10-year flood. Documented evidence shall also be provided that the riser will control the WQ_v if the stormwater pond is used to meet this requirement. The riser shall also be located within the embankment for maintenance access, safety and aesthetics. Access to the riser is to be provided by lockable manhole covers (the principal spillway opening can be "fenced" with pipe or rebar at 8 inch intervals for safety purposes). The principal spillway shall also be equipped with a trash rack that provides access for maintenance.

A non-clogging low flow orifice must be provided for the WQ_v. The low flow orifice shall have a minimum diameter of 3 inches, and shall be adequately protected from clogging by an acceptable external trash rack. The preferred method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point one foot below the normal pool elevation. Alternative methods are to employ a broad crested rectangular weir or a V-notch weir protected by a half-round CMP that extends at least 12 inches below the normal pool. Horizontal perforated pipe protected by geotextile and gravel shall not be used. Vertical perforated pipes shall not be used.

The emergency spillway may either be combined with the outlet works or be a separate structure or channel meeting the following criteria:

- Emergency spillways shall be designed so that their crest elevation is 0.5 feet or more above the maximum water surface elevation in the detention facility attained by the 100-year storm event *(1)*.

- In cases where the emergency spillway is not regulated by either State or Federal agencies, the emergency spillway shall be designed to pass the 100-year storm with 1 foot of freeboard (or as designated) from the design stage to the top of dam, assuming zero available storage in the basin and zero flow through the primary outlet *(1)*.

Each stormwater pond shall have a drain pipe that can completely or partially drain the pond. The drain pipe shall have an elbow within the pond to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours. The pond drain should be sized one pipe size greater than the calculated design diameter. Care shall be exercised during pond drawdowns to prevent downstream discharge of sediments or anoxic water and rapid drawdown. The Engineering Department shall be notified before draining a pond.

The pond drain shall be equipped with an adjustable valve (typically a handwheel activated knife or gate valve). Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner. To prevent vandalism, the handwheel should be chained to a ringbolt, or other fixed object

Sharp-crested weir flow equations for no end contractions, two end contractions and submerged discharge conditions are presented below, followed by equations for broad-crested weirs, V-notch weirs, and orifices, or combinations of these facilities. If culverts are used as outlets works, procedures presented in the Culverts Chapter should be used to develop stage-discharge data. When analyzing release rates, the tailwater influence of the principal spillway culvert on the control structure (orifice and/or weirs) must be considered to determine the effective head on each opening. Slotted riser pipe outlet facilities shall not be used.

5.2.3.1 Sharp-Crested Weirs

A sharp-crested weir with no end contractions is illustrated in Figure 5-7. The discharge equation for this configuration is *(4)*:

$$Q = [3.27 + 0.4(H/H_c)]\, LH^{1.5} \qquad (5.3)$$

where:
Q = discharge, ft^3/s
H = head above weir crest excluding velocity head, ft
H_c = height of weir crest above channel bottom, ft
L = horizontal weir length, ft

A sharp-crested weir with two end contractions is illustrated in Figures 5-7 and 5-8. The discharge equation for this configuration is *(4)*:

$$Q = [3.27 + 0.4(H/H_c)]\,(L - 0.2H)\, H^{1.5} \qquad (5.4)$$

where: Variables are the same as Equation 5.1.

A sharp-crested weir will be affected by submergence where the tailwater rises above the weir-crest elevation. The result will be that the discharge over the weir will be reduced. The discharge equation for a sharp-crested submerged weir is *(3)*:

$$Q_S = Q_f(1 - (H_2/H_1)^{1.5})^{0.385} \qquad (5.5)$$

where:
Q_s = submergence flow, ft^3/s
Q_f = free flow, ft^3/s
H_1 = upstream head above crest, ft
H_2 = downstream head above crest, ft

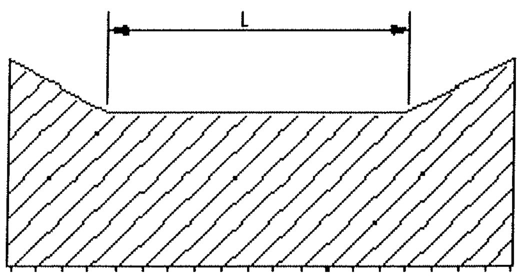


FIGURE 5-7.
Sharp-Crested Weir (No End Contractions)

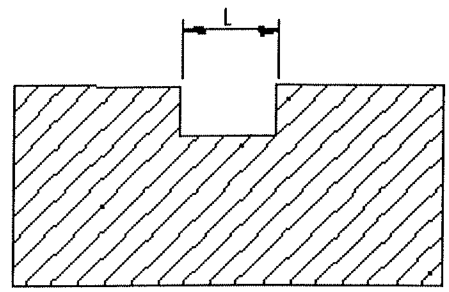


FIGURE 5-8.
Sharp-Crested Weir (Two End Contractions)

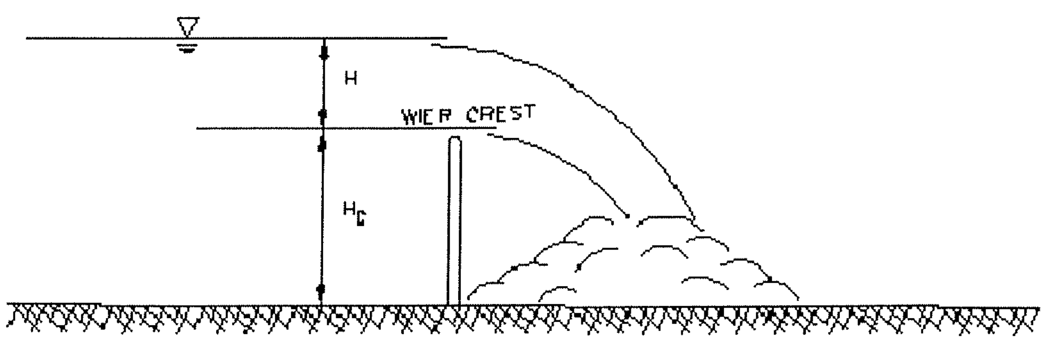


FIGURE 5-9. Sharp-Crested Weir and Head

5.2.3.2 Broad-Crested Weirs

The equation generally used for the broad-crested weir is *(3)*:

$$Q = CLH^{1.5} \tag{5.6}$$

where:

Q = discharge, ft^3/s
C = broad-crested weir coefficient
L = broad-crested weir length, ft
H = head above weir crest, ft

If the upstream edge of a broad-crested weir is so rounded as to prevent contraction and if the slope of the crest is as great as the loss of head due to friction, flow will pass through critical depth at the weir crest; this gives the maximum C value of 3.087. For sharp corners on the broad-crested weir, a minimum C value of 2.6 should be used. Additional information on C values as a function of weir crest breadth and head is given in Table 5-1.

TABLE 5-1. Broad-Crested Weir Coefficient *C* Values as a Function of Weir Crest Breadth and Head (ft)

Measured Head, H[1] (ft)	Breadth of the Crest of Weir (ft)										
	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	10.00	15.00
0.2	2.80	2.75	2.69	2.62	2.54	2.48	2.44	2.38	2.34	2.49	2.68
0.4	2.92	2.80	2.72	2.64	2.61	2.60	2.58	2.54	2.50	2.56	2.70
0.6	3.08	2.89	2.75	2.64	2.61	2.60	2.68	2.69	2.70	2.70	2.70
0.8	3.30	3.04	2.85	2.68	2.60	2.60	2.67	2.68	2.68	2.69	2.64
1.0	3.32	3.14	2.98	2.75	2.66	2.64	2.65	2.67	2.68	2.68	2.63
1.2	3.32	3.20	3.08	2.86	2.70	2.65	2.64	2.67	2.66	2.69	2.64
1.4	3.32	3.26	3.20	2.92	2.77	2.68	2.64	2.65	2.65	2.67	2.64
1.6	3.32	3.29	3.28	3.07	2.89	2.75	2.68	2.66	2.65	2.64	2.63
1.8	3.32	3.32	3.31	3.07	2.88	2.74	2.68	2.66	2.65	2.64	2.63
2.0	3.32	3.31	3.30	3.03	2.85	2.76	2.27	2.68	2.65	2.64	2.63
2.5	3.32	3.32	3.31	3.28	3.07	2.89	2.81	2.72	2.67	2.64	2.63
3.0	3.32	3.32	3.32	3.32	3.20	3.05	2.92	2.73	2.66	2.64	2.63
3.5	3.32	3.32	3.32	3.32	3.32	3.19	2.97	2.76	2.68	2.64	2.63
4.0	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.70	2.64	2.63
4.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.74	2.64	2.63
5.0	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.64	2.63
5.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.64	2.63

[1]Measured at least $2.5H$ upstream of the weir.

Source: Reference *(3)*.

5.2.3.3 V-Notch Weirs

The discharge through a V-notch weir can be calculated from the following equation *(3)*:

$$Q = 2.5 \tan(q/2) H^{2.5} \tag{5.7}$$

where:

Q = discharge, ft^3/s
q = angle of V-notch, degrees
H = head on apex of notch, ft

5.2.3.4 Orifices

Pipes smaller than 12 in. may be analyzed as a submerged orifice if H/D is greater than 1.5. For square-edged entrance conditions:

$$Q = 0.6A(2gH)^{0.5} \tag{5.8}$$

where:

Q = discharge, ft^3/s
A = cross-section area of pipe, ft^2
g = acceleration due to gravity, 32.2 ft/s^2
D = diameter of pipe, ft
H = head on pipe, from the center of pipe to the water surface, ft *

* Where the tailwater is higher than the center of the opening, the head is calculated as the difference in water surface elevations.

5.2.4 *Discharge Systems*

For site-specific runoff, the effectiveness of local stormwater ponds used for detention can be acknowledged in the design of any onsite downstream drainage facilities, assuming that the stormwater ponds comply with all criteria and that they are properly constructed and maintained.

In the case of regional stormwater ponds, sizing of the system below the control structure shall be for the total improved peak runoff tributary to the structure, with no allowance for detention unless approved in writing by the Engineering Department.

In the event the Engineer desires to incorporate the flow reduction benefits of existing upstream stormwater ponds, the following field investigations and hydrologic analysis shall be required:

- A field survey of the existing physical characteristics of both the outlet structure and ponding volume. Any departure from the original engineer's design must be accounted for. If a dual use for the stormwater pond exists, then this also must be accounted for.

- A comprehensive hydrologic analysis that simulates the attenuation of the contributing area ponds. This should not be limited to a linear additive analysis, but rather should consist of a network of hydrographs that considers incremental timing of discharge and potential coincidence of outlet peaks.

Please note that under no circumstances will the previously approved construction plans of the upstream pond or ponds suffice as an adequate analysis. While the responsibility of the individual site or subdivision plans rests with the Engineer of Record, any subsequent engineering analysis must assure that all the incorporated ponds work collectively.

5.2.5 *Conveyance Criteria*

Conveyance shall be provided which does not cause erosion. Primary outlet works, emergency spillways, and conveyance system entrances to stormwater ponds shall be equipped with energy dissipating devices as necessary to limit erosion on receiving channels *(1)*.

5.2.5.1 Inlet Protection

A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. Inlet areas shall be protected to reduce erosion.

5.2.5.2 Adequate Outfall Protection

Outfalls shall be constructed such that they do not increase erosion or have undue influence on the downstream geomorphology of the stream.

Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement shall be used at the spillway outlet.

The channel immediately below the pond outfall shall be modified to prevent erosion and conform to natural dimensions in the shortest possible distance, typically by use of large rip-rap placed over filter cloth.

A stilling basin or outlet protection shall be used to reduce flow velocities from the principal spillway to non-erosive velocities.

If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. Excessive use of rip-rap should be avoided to reduce stream warming.

5.2.5.3 Pond Liners

When a pond is located in karst topography, gravelly sands or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a minimum permeability of 1×10^{-5} cm/sec), (b) a 30 ml poly-liner (c) bentonite, or (d) use of chemical additives (see NRCS Agricultural Handbook No. 387, dated 1971, or Engineering Field Manual).

5.2.6 *Water Quality Criteria*

5.2.6.1 Pretreatment Criteria

Each stormwater pond used to meet water quality requirements shall have a sediment forebay or equivalent upstream pretreatment. The forebay shall consist of a separate cell, formed by an acceptable barrier.

The forebay shall be 4 to 6 feet deep. It shall be sized to contain 0.1 inches of runoff per impervious acre of contributing drainage. The forebay storage volume counts toward the total WQ_v requirement. Exit velocities from the forebay shall be non-erosive.

Direct maintenance access for appropriate equipment shall be provided to the forebay.
The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

5.2.6.2 Treatment Criteria

Stormwater ponds used to meet water quality requirement shall be designed to capture and treat the computed WQ_v through any combination of permanent pool, extended detention (ED) or wetland. Stormwater ponds shall release the WQ_v over a minimum period of 24-hours and within a maximum of 72-hours.

It is generally desirable to provide water quality treatment off-line when topography, head and space permit (e.g., apart from stormwater quantity storage).

Water quality storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and wetland).

If a micropool extended detention pond is constructed, the micropool shall be sized to contain 0.1 inches per impervious acre of contributing drainage.

5.2.7 *Landscaping Criteria*

5.2.7.1 Landscaping Plan

A landscaping plan for a stormwater pond and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be vegetatively stabilized and established.

Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED wetlands) or within shallow areas of the pool itself.

The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.

The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil.

As a rule of thumb, planting holes should be 3 times deeper and wider than the diameter of the rootball (of balled and burlap stock), and 5 times deeper and wider for container grown stock. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

5.2.7.2 Pond Buffers and Setbacks

Pond buffers can be important in providing ample space for access and safety. The buffer can be planted or left in trees to discourage resident goose populations.

A pond buffer shall be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer shall be contiguous with other buffer areas, that are required by existing regulations (e.g., stream buffers). An additional setback may be provided to permanent structures.

Woody vegetation may not be planted on or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.

Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.

5.2.8 *Ownership of Stormwater Ponds*

Ownership of stormwater ponds in residential subdivisions accepted by the City shall be vested in the City of Fort Smith with the filing of the final plat. The Developer shall warrant the operation of the drainage system for 2 years after acceptance by the City by a Maintenance Bond provided by the Developer's Contractor or the Developer. The bond shall be required to be extended until 2 years after all phases of the subdivision or development that substantially drain into the stormwater pond are completed.

Ownership of stormwater ponds in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

5.2.9 *Maintenance of Stormwater Ponds*

When ownership of a stormwater pond is not vested in the City of Fort Smith, the maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or the permitting process.

Stormwater ponds, when required, are to be built in conjunction with storm sewer installation and/or grading. Since these facilities are intended to control increased runoff, they must be partially or fully operational soon after the clearing of the vegetation. Silt and debris connected with construction activities shall be removed periodically from the detention area and control structure to maintain the facility's storage capacity.

Maintenance of stormwater ponds is divided into two components – short term maintenance and long term maintenance. Requirements for both are discussed in the following sections. Requirements for maintenance access are also discussed below.

5.2.9.1 Short Term Maintenance

For public stormwater ponds, short term or annual maintenance is the responsibility of the developer or property owners' association for two years after acceptance of the final plat or filing of the last subdivision phase that substantially adds storm water to a stormwater pond. The items considered short term maintenance are as follows:

- Sediment removal
- Outlet cleaning
- Mowing
- Herbicide Spraying
- Litter Control

5.2.9.2 Long Term Maintenance

Long term maintenance includes removal of sediment from the basin and outlet structure. Studies show that to be needed once every 5 to 10 years. Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been lost. Where the City has accepted the stormwater pond, the City is responsible for long term maintenance. Where basins are not accepted by the City, the property owner is responsible for the long term maintenance.

5.2.9.3 Maintenance Access

A maintenance right of way or easement shall extend to the stormwater pond from a public road. Maintenance access shall be at least 20 feet wide; have a maximum slope of no more than 15%; and should be appropriately stabilized to withstand maintenance equipment and vehicles. The maintenance access shall extend to the forebay, safety bench, riser, and outlet and be designed to allow vehicles to turn around.

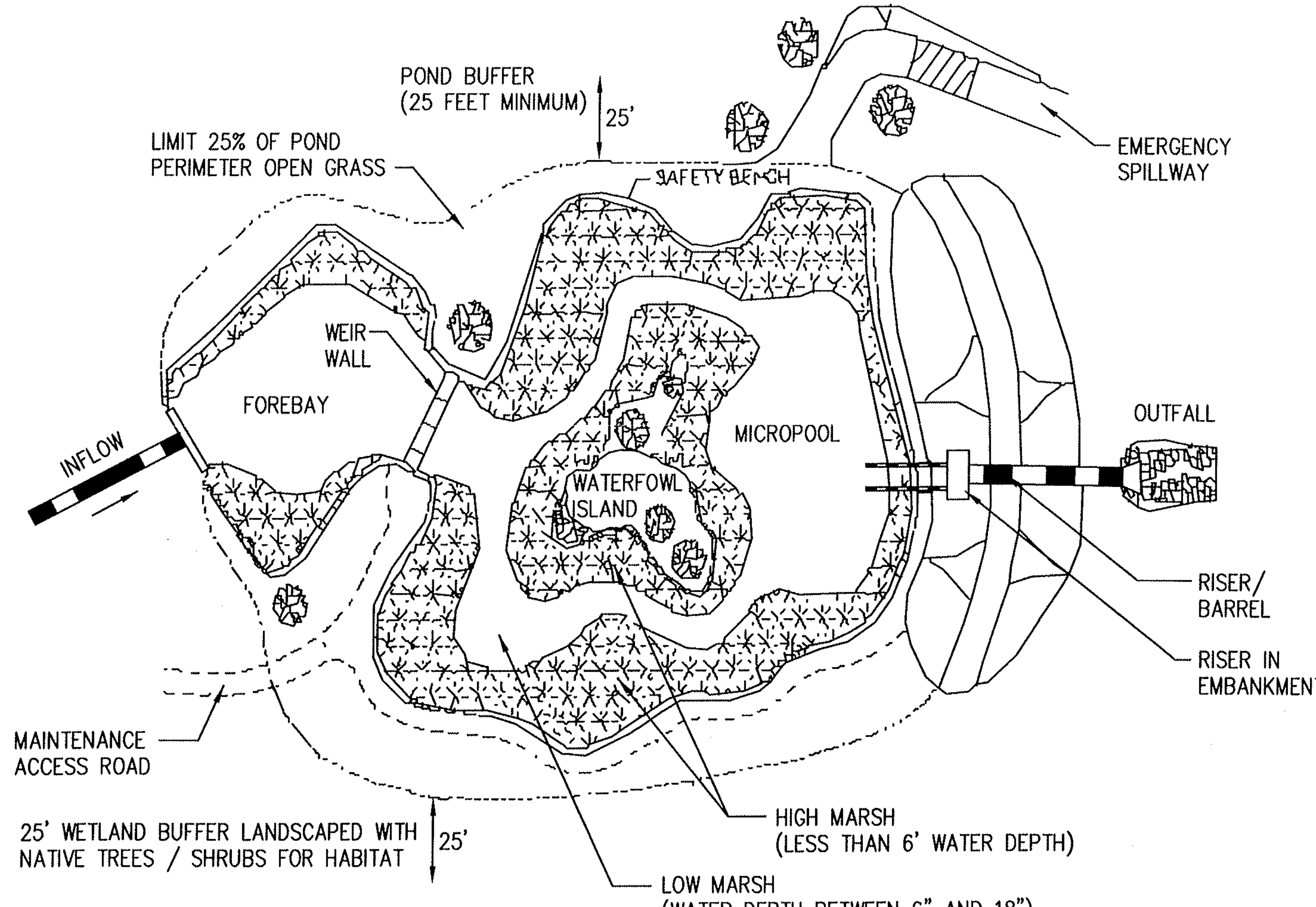
5.3 DESIGN CRITERIA – WETLANDS

Stormwater wetlands are practices that create shallow marsh areas to treat urban stormwater and often incorporate small permanent pools and/or extended detention storage to achieve the full WQ_v. Design variants include:

- Shallow Wetland (Figure 5-10)
- ED Shallow Wetland (Figure 5-11)
- Pond/Wetland System (Figure 5-12)
- "Pocket" Wetland (Figure 5-13)

Stormwater wetlands may be used in residential, private, commercial, and industrial subdivisions and developments to meet the detention and WQ_v requirements.

All of the pond criteria presented in 5.2 DESIGN CRITERIA – STORMWATER PONDS also apply to the design of stormwater wetlands. Additional criteria that govern the geometry and establishment of created wetlands are presented in this section.



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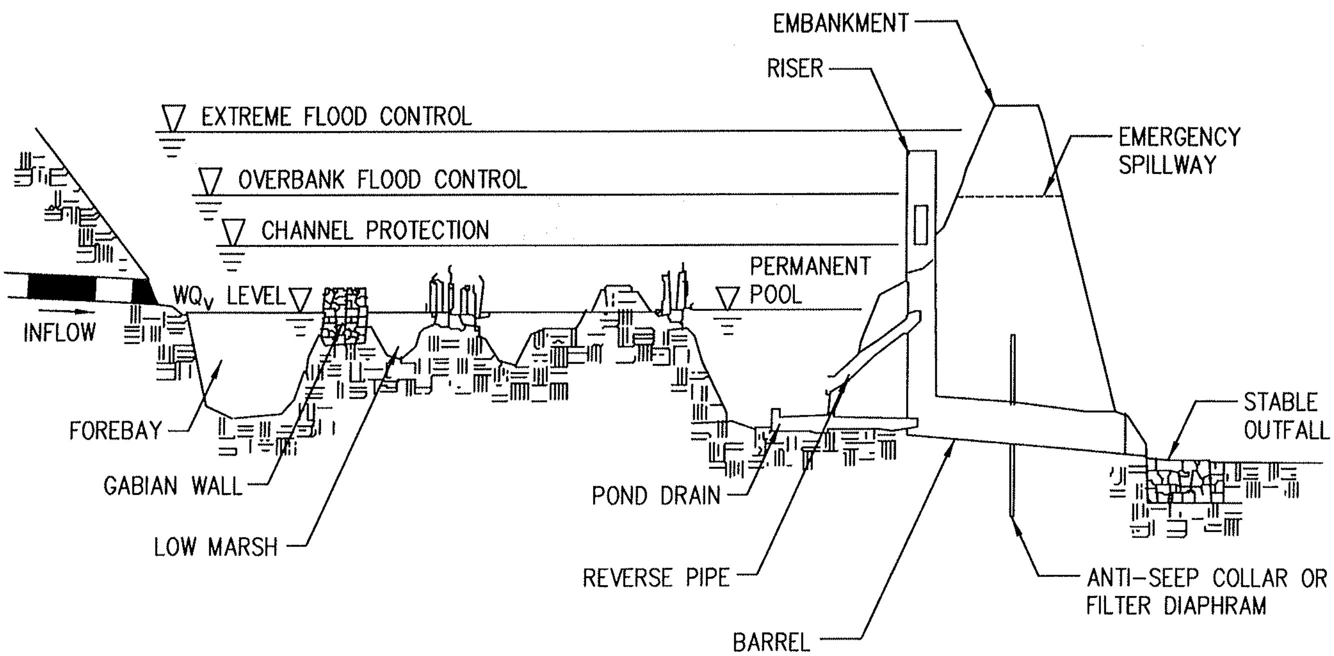
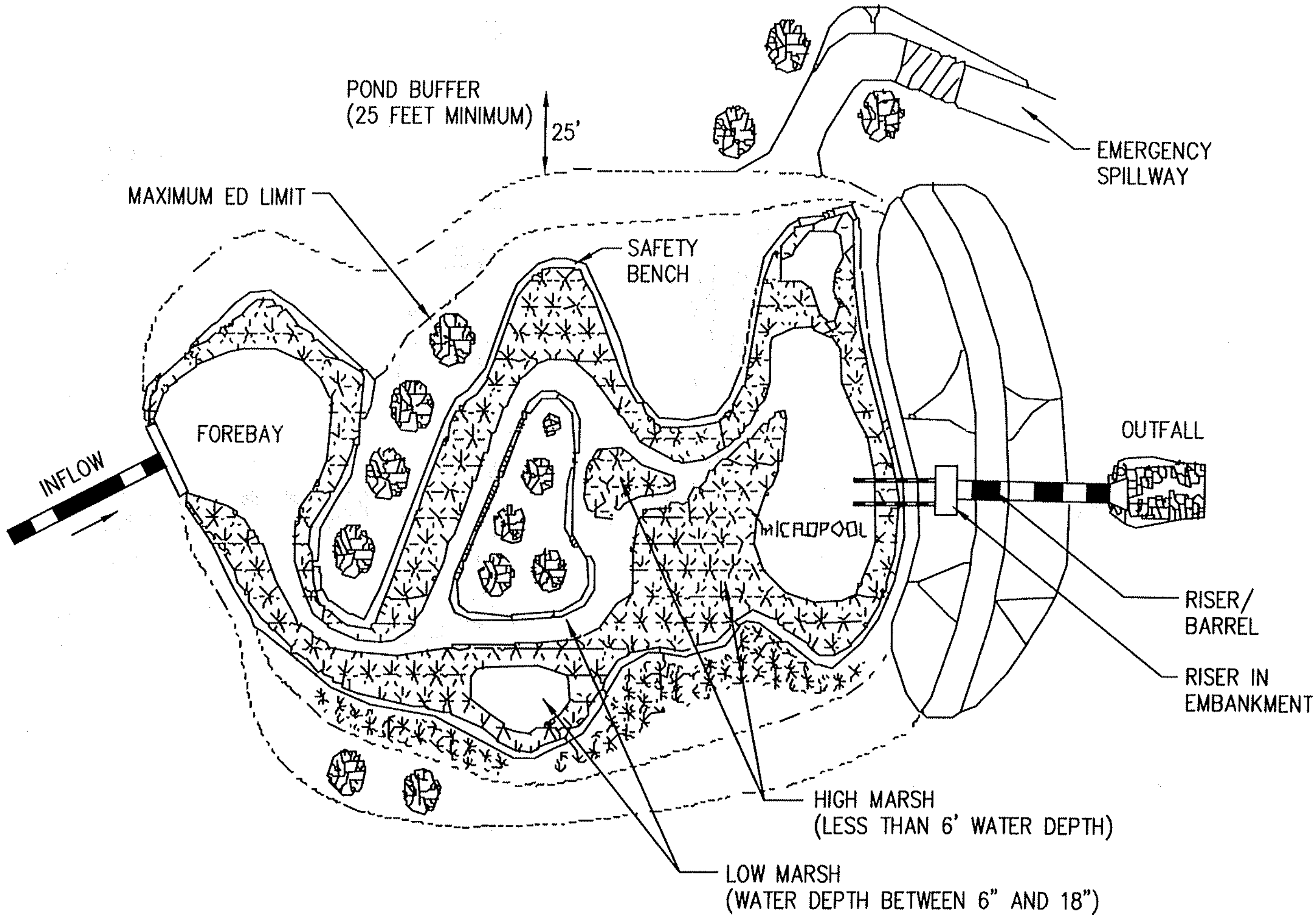


PROFILE

FIGURE 5-10. Shallow Wetland



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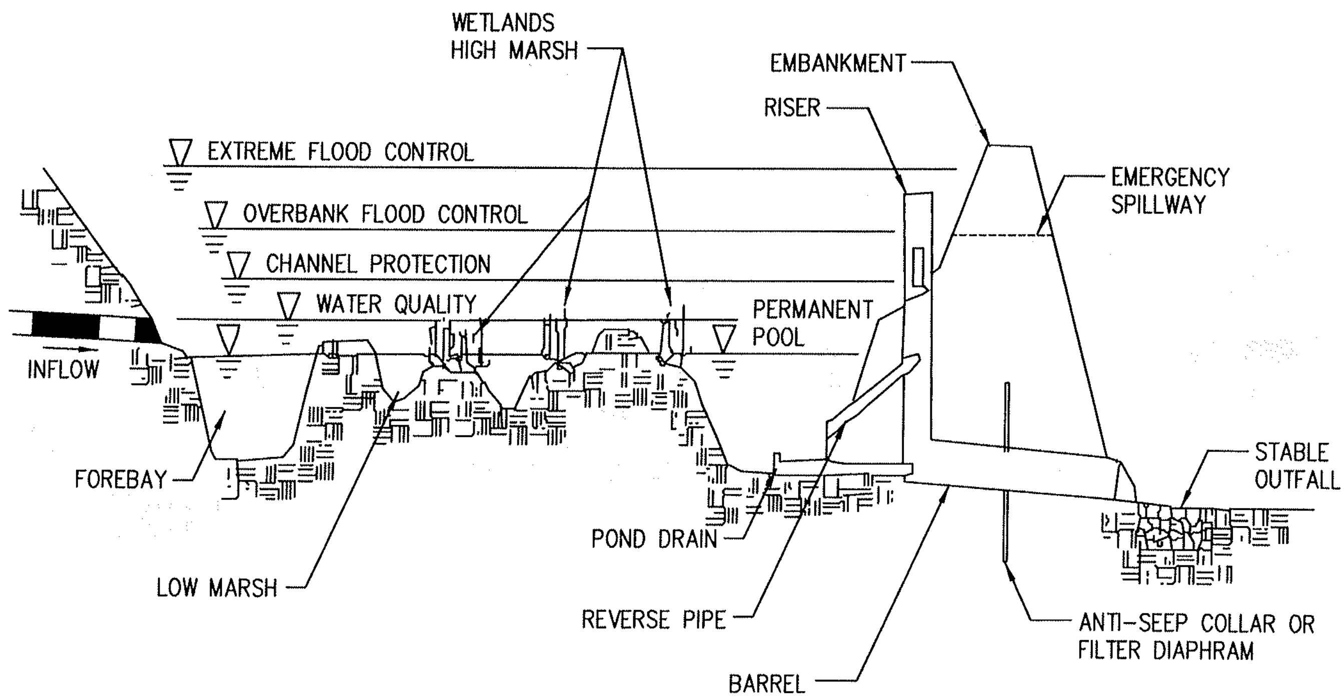
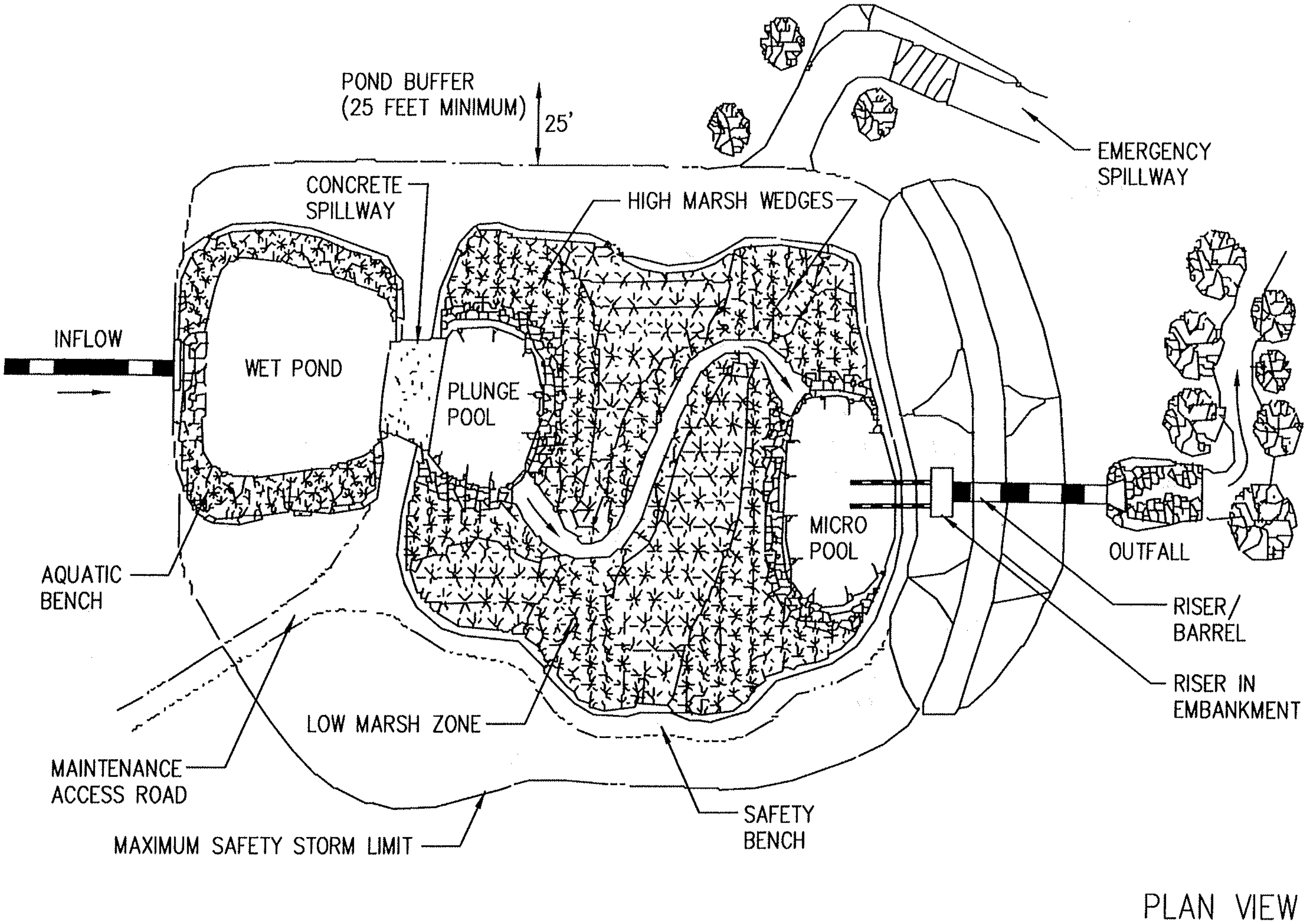


PROFILE

FIGURE 5-11. Extended Detention Shallow Wetland



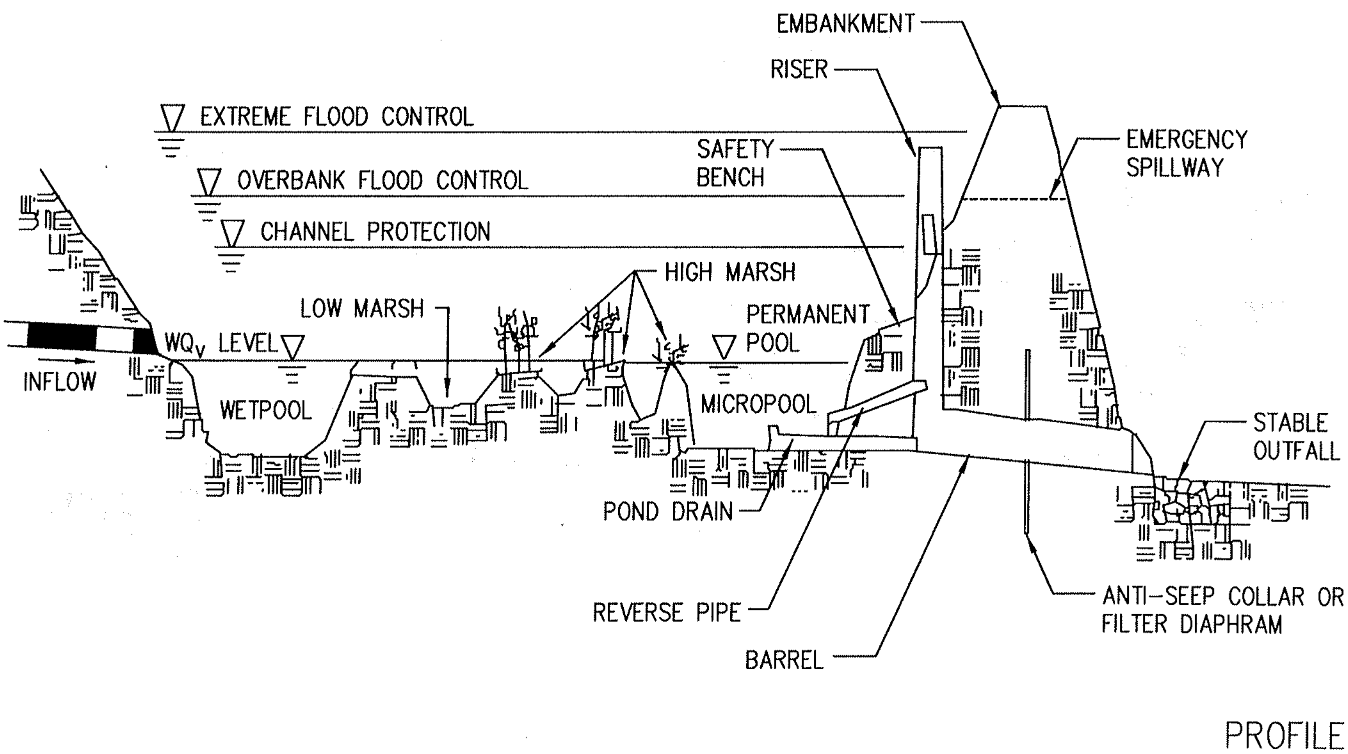
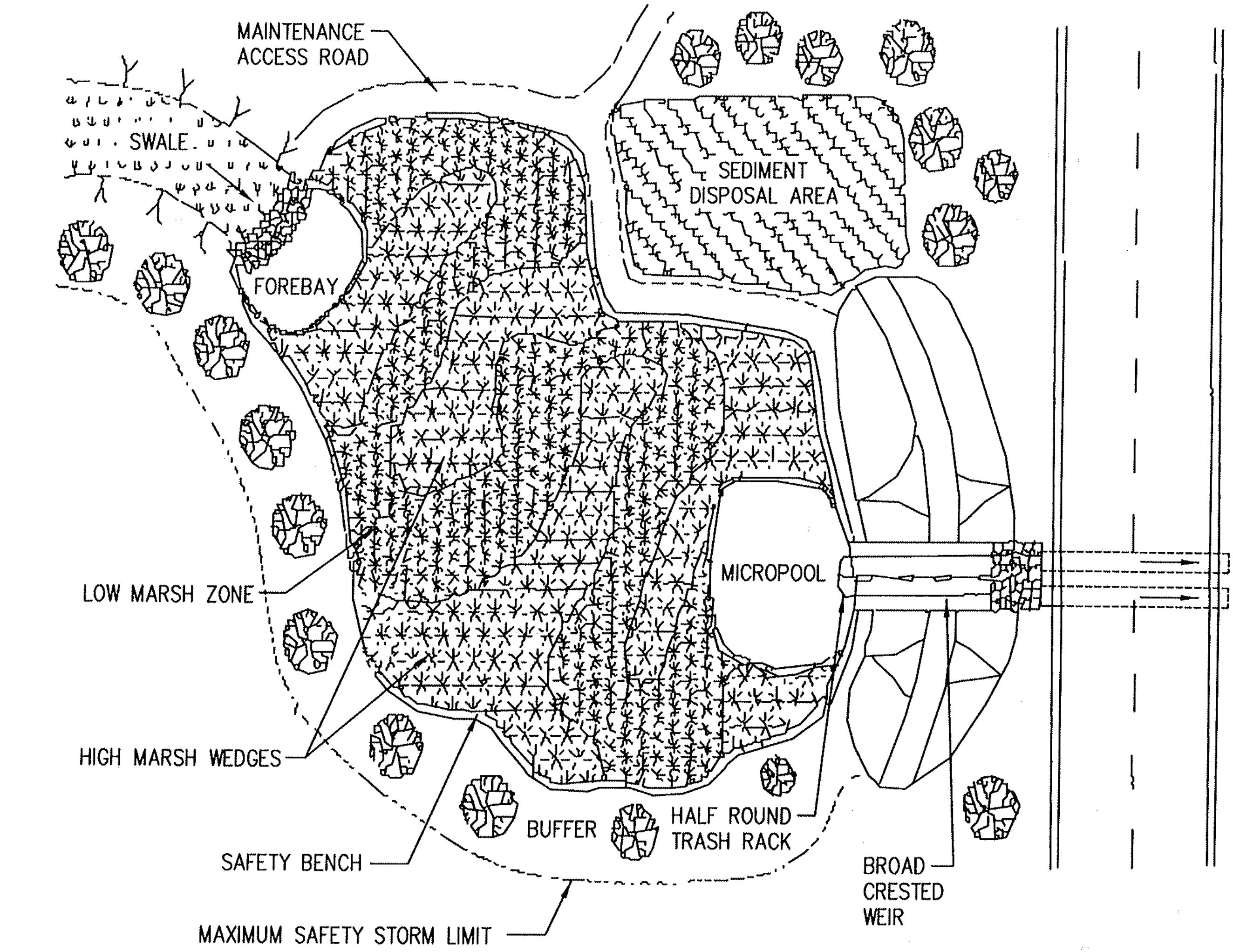


FIGURE 5-12. Pond/Wetland System



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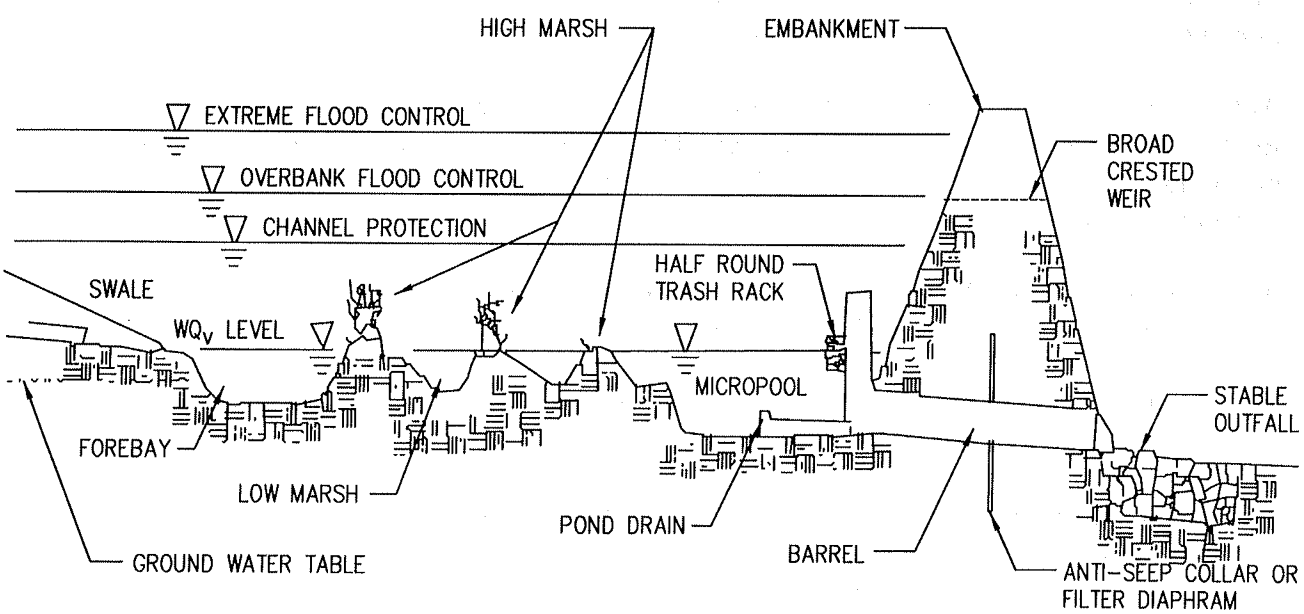


PROFILE

FIGURE 5-13. "Pocket" Wetland

5.3.1 *Feasability Criteria*

A water balance shall be performed to demonstrate that a stormwater wetland can withstand a significant drought at summer evaporation rates without completely drawing down.

Stormwater wetlands shall not be located within existing jurisdictional wetlands.

5.3.2 *Conveyance Criteria*

Flowpaths from the inflow points to the outflow points of stormwater wetlands shall be maximized. A minimum flowpath of 2:1 (length to relative width) shall be provided across the stormwater wetland. This path may be achieved by constructing internal berms (e.g., high marsh wedges or rock filter cells).

Microtopography is encouraged to enhance wetland diversity.

5.3.3 *Pretreatment Criteria*

Sediment regulation is critical to sustain stormwater wetlands. Consequently, a forebay shall be located at the inlet, and a micropool shall be located at the outlet. For forebay design criteria, consult 5.2 DESIGN CRITERIA – STORMWATER PONDS.

A micropool three to six feet deep shall be used to protect the low flow pipe from clogging and prevent sediment resuspension.

5.3.4 *Treatment Criteria*

The surface area of the entire stormwater wetland shall be at least one percent of the contributing drainage area (1.5% for shallow marsh design).

At least 25% of the WQ_v shall be in deepwater zones with a depth greater than four feet. The forebay and micropool may meet this criteria. In addition, the deepwater zones serve to keep mosquito populations in check by providing habitat for fish and other pond life that prey on mosquito larvae.

A minimum of 35% of the total surface area can have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches.

The bed of the wetland shall be graded to create maximum internal flow path and microtopography.

If extended detention is utilized in a stormwater wetland, the WQ_v -ED volume shall not comprise more than 50% of the total WQ_V, and its maximum water surface elevation shall not extend more than three feet above the permanent pool.

To promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. The rock should be one to three inches in diameter, placed up to the normal pool elevation, and open to flow-through from either direction.

5.3.5 *Landscaping Criteria*

A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.

Structures such as fascines, coconut rolls, straw bales, or filter fence can be used to create shallow marsh cells in high energy areas of the stormwater wetland.

The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.

A wetland plant buffer shall extend 25 feet outward from the maximum water surface elevation, with an additional 15 foot setback to structures.

5.3.6 *Wetland Establishment*

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from aquatic plant nurseries. The following guidance is suggested when transplants are used to establish a wetland.

Plant only during the transplanting window. Wetland plants need a full growing season to build root reserves needed to get through the winter. If at all possible, plants should be ordered at least three months in advance to ensure the availability of the desirable species.

The optimal depth requirements for several common species of emergent wetland plants are often six inches or less.

To add diversity to the wetland, five to seven species of emergent wetland plants should be planted.

No more than half the wetland surface area needs to be planted. If the appropriate planting depths are achieved, the entire wetland should be colonized within three years.

The wetland area should be subdivided into separate planting zones of more or less constant depth.

One plant species should be planted within each flagged planting zone, based on approximate depth requirements.

Individual plants should be planted 18 inches on center in clumps.

Post-nursery care of wetland plants is very important in the interval between delivery of the plants and their subsequent planting, as they are prone to dessication. Stock should be frequently watered and shaded while on-site.

A wet hydroseed mix should be used to establish permanent vegetative cover in the buffer outside the permanent pool. For rapid germination, scarify the soil to ½ inch prior to hydroseeding. Alternatively, grass species can be used as a temporary cover for the wet species.

Because most stormwater wetlands are excavated to deep subsoils, they often lack the nutrients and organic matter needed to support vigorous growth of wetland plants. At these sites, three to six inches of topsoil or wetland mulch should be added to all depth zones in the wetland from one foot below the normal pool to six inches above. Wetland mulch is preferable to topsoil if it is available.

The stormwater wetland should be staked at the onset of the planting season. Depths in the wetland should be measured to the nearest inch to confirm original planting zones. At this time, it may be necessary to modify the pondscaping plan to reflect altered depths or the availability of wetland plant stock. Surveyed planting zones should be marked on an "as-built" or design plan, and located in the field using stakes or flags. The wetland drain should be fully opened at least three days prior to the planting dates (which should coincide with the delivery date for the wetland plant stock).

Wetland mulch is another technique to establish a wetland plant community which utilizes the seedbank of wetland soils to provide the propagules for marsh development. The majority of the seedbank is contained within the upper six inches of the donor wetland soils. The mulch is best collected at the end of the growing season. Best results are obtained when the mulch is spread three to six inches deep over the high marsh and semi-wet zones of the wetland (-6 inches to +6 inches relative to the normal pool).

In some cases, the use of "volunteer wetlands," allowing cattails and phragmites to colonize may be appropriate.

Donor soils for wetland mulch should not be removed from natural wetlands.

5.3.7 *Ownership of Wetlands*

Ownership of stormwater wetlands in residential subdivisions accepted by the City shall be vested in the City of Fort Smith with the filing of the final plat. The Developer shall warrant the operation of the drainage system for 2 years after acceptance by the City by a Maintenance Bond provided by the Developer's Contractor or the Developer. The bond shall be required to be extended until 2 years after all phases of the subdivision or development that substantially drain into the stormwater wetland are completed.

Ownership of stormwater wetlands in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

5.3.8 *Maintenance of Wetlands*

Stormwater wetlands shall be required to meet all the maintenance requirements found in Section 5.2.9 *Maintenance of Stormwater Ponds.* In addition, stormwater wetlands shall also be required to meet the criteria below.

5.3.8.1 Minimum Coverage

If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.

5.4 DESIGN CRITERIA – STORMWATER INFILTRATION

Stormwater infiltration practices capture and temporarily store the WQ_v before allowing it to infiltrate into the soil over a two day period. Design variants include:

- Infiltration Trench (Figure 5-14)
- Infiltration Basin (Figure 5-15)

Extraordinary care must be taken to assure that long-term infiltration rates are achieved through post construction inspection and long-term maintenance.

Stormwater infiltration practices may be used in private, commercial, and industrial subdivisions and developments to meet the WQ_v requirement. In certain limited cases, with proper documentation, they may also be used in private, commercial, and industrial subdivisions and developments to meet the detention requirement.

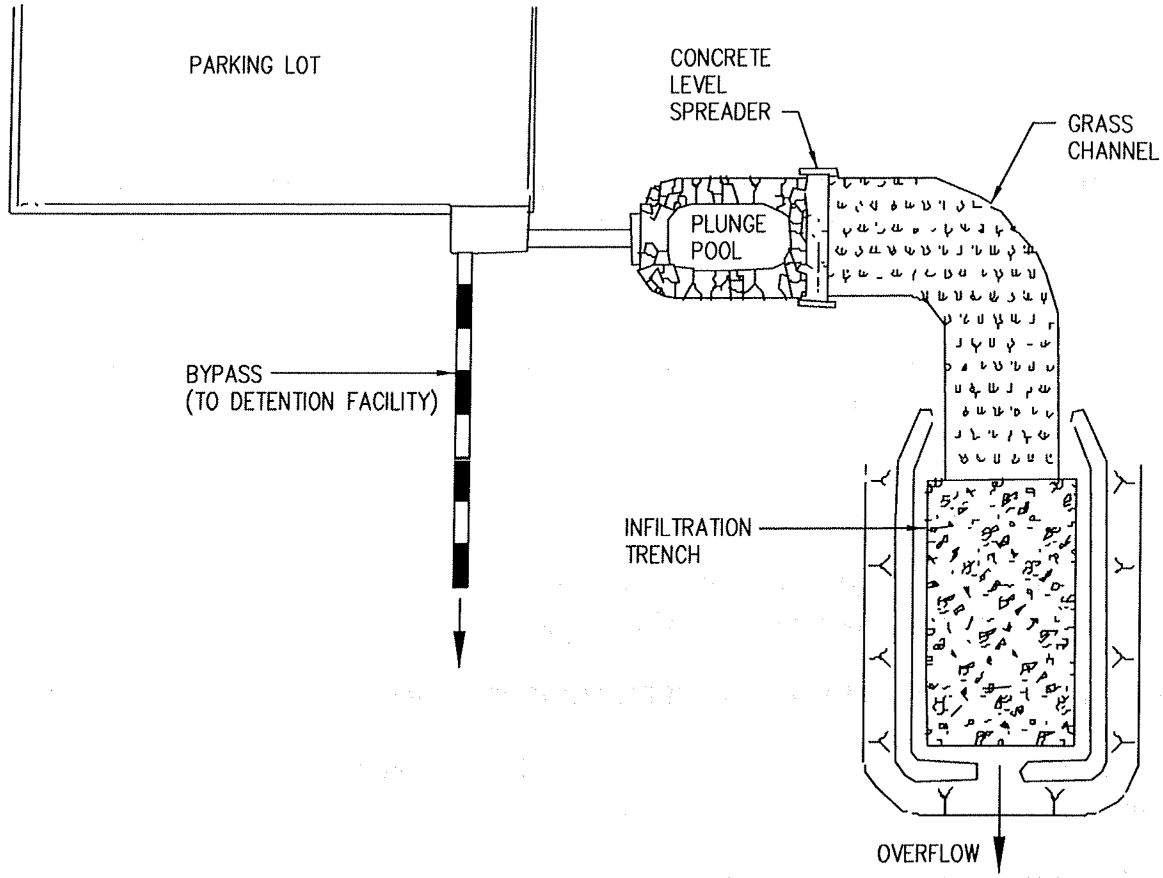
5.4.1 *Feasibility Criteria*

To be suitable for infiltration, underlying soils must have an infiltration rate (f_c) of 0.52 inches per hour or greater, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 sf, with a minimum of two borings per facility (taken within the proposed limits of the facility).

Soils shall also have a clay content of less than 20% and a silt/clay content of less than 40%.

Infiltration cannot be located on slopes greater than 6% or within fill soils.

To protect groundwater from possible contamination, runoff from designated hotspot land uses or activities cannot be infiltrated.



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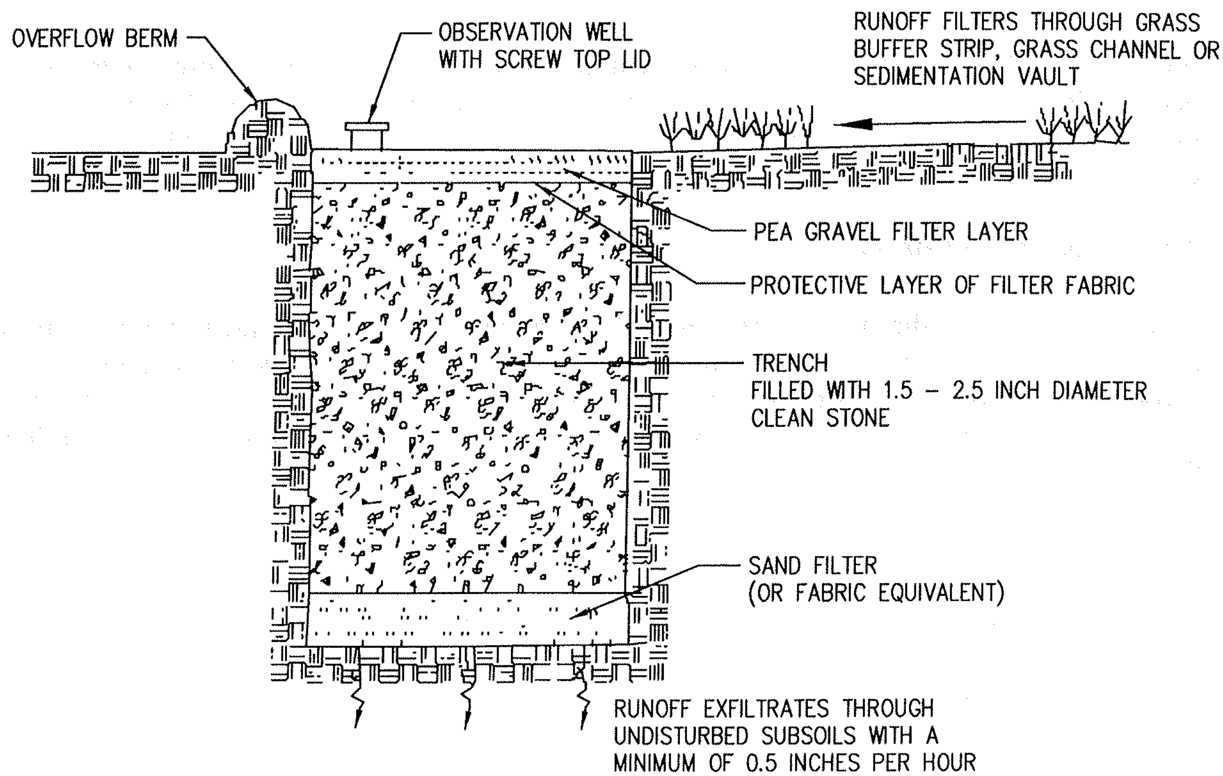


SECTION

FIGURE 5–14. Infiltration Trench

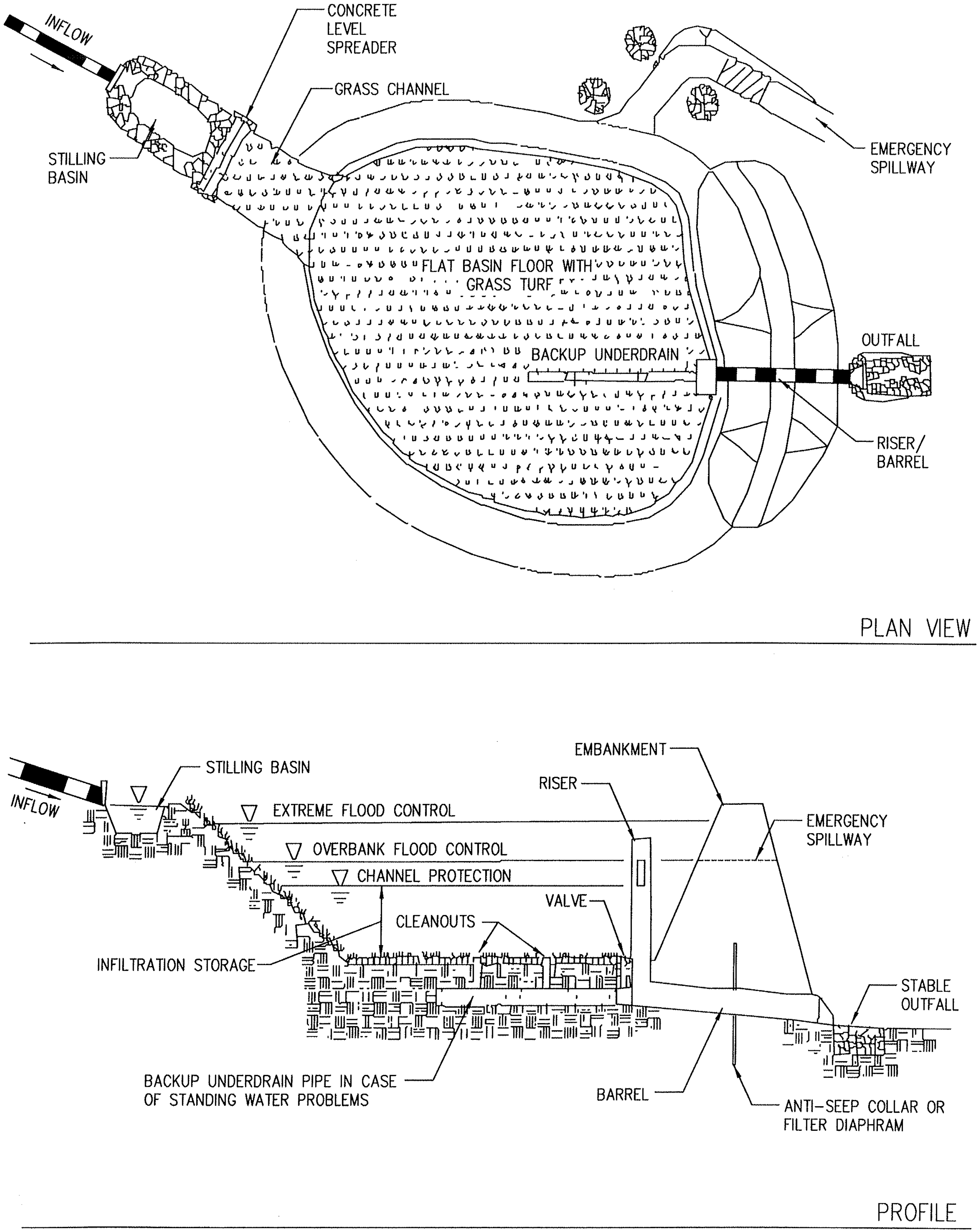


FIGURE 5-15. Infiltration Basin

The bottom of the infiltration facility shall be separated by at least four feet vertically from the seasonally high water table or bedrock layer, as documented by on-site soil testing.

Infiltration facilities can be located at least 100 feet horizontally from any water supply well.

Infiltration practices cannot be placed in locations that cause water problems to downgrade properties. Infiltration facilities must be setback at least 25 feet down-gradient from structures.

The maximum contributing area to an individual infiltration practice shall be less than 5 acres.

5.4.2 *Conveyance Criteria*

The overland flow path of surface runoff exceeding the capacity of the infiltration system can be evaluated to preclude erosive concentrated flow during the overbank events. If computed flow velocities exceed the non-erosive threshold, a overflow channel shall be provided to a stabilized water course.

All infiltration systems should be designed to fully de-water the entire WQ_v within 48 hours after the storm event.

If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice must be designed as an off-line practice. Pretreatment shall be provided for storm drain pipes systems discharging directly to infiltration systems.

Adequate stormwater outfalls shall be provided for the overflow associated with the ten year design storm event (non-erosive velocities on the down-slope).

5.4.3 *Pretreatment Criteria*

5.4.3.1 Pretreatment Volume

A minimum pretreatment volume of at least 25% of the WQ_v must be provided prior to entry to an infiltration facility, and can be provided in the form of a sedimentation basin, sump pit, grass channel, plunge pool or other measure.

Exit velocities from pretreatment chambers shall be non-erosive (5 fps) during the two year design storm. If the f_c for the underlying soils is greater than 2.00 inches per hour, 50% of the WQ_v shall be treated by another method prior to entry into an infiltration facility.

5.4.3.2 Pretreatment Techniques to Prevent Clogging

Each infiltration system can have redundant methods to protect the long term integrity of the infiltration rate. Three or more of the following techniques must be installed in every facility:

- grass channel

- grass filter strip (minimum 20 feet and only if sheet flow is established and maintained)
- bottom sand layer
- upper filter fabric layer
- use of washed bank run gravel as aggregate

The sides of infiltration practices shall be lined with an acceptable filter fabric that prevents soil piping.

5.4.4 *Treatment Criteria*

Infiltration practices shall be designed to exfiltrate the entire WQ_v through the floor of each practice.

Infiltration practices are best used in conjunction with other practices, and often a stormwater pond is still needed downstream to meet the detention requirement.

A porosity value (V_v/V_t) of 0.32 can be used to design stone reservoirs for infiltration practices.

5.4.5 *Landscaping Criteria*

A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility. Infiltration trenches shall not be constructed until all of the contributing drainage area has been completely stabilized.

5.4.6 *Ownership of Stormwater Infiltration*

Ownership of stormwater infiltration practices in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

Stormwater infiltration practices may not be used in residential subdivisions.

5.4.7 *Maintenance of Stormwater Infiltration*

The maintenance responsibility for a stormwater infiltration system shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or the permitting process.

Infiltration practices must never serve as a sediment control device during site construction phase. In addition, the Erosion and Sediment Control plan for the site shall clearly indicate how sediment entry will be prevented from entering the infiltration site. Normally, this is done by using diversion berms around the perimeter of the infiltration practice, along with immediate vegetative stabilization and/or mulching.

An observation well shall be installed in every infiltration trench, consisting of an anchored six-inch diameter perforated PVC pipe with a lockable cap installed flush with the ground surface.

Direct access shall be provided to infiltration practices for maintenance and rehabilitation. If a stone reservoir or perforated pipe is used to temporarily store runoff prior to infiltration, the practice shall not be covered by an impermeable surface.

Infiltration designs shall include dewatering methods in the event of failure. This can be accomplished with underdrain pipe systems that accomodate drawdown.

5.5 DESIGN CRITERIA – STORMWATER FILTERING SYSTEMS

Stormwater filtering system capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Design variants include:

- Surface Sand Filter (Figure 5-16)
- Underground Sand Filter (Figure 5-17)
- Perimeter Sand Filter (Figure 5-18)
- Organic Filter (Figure 5-19)
- Bioretention (Figure 5-20)

Stormwater filtering systems may be used in private, commercial, and industrial subdivisions and developments to meet the WQ_v requirement. Filtering systems shall not be designed to provide the detention requirement. Filtering practices shall be combined with a separate facility to provide detention.

5.5.1 *Feasibility Criteria*

Most stormwater filters normally require two to six feet of head. The perimeter sand filter (Figure 5-18), however, can be designed to function with as little as one foot of head.

The maximum contributing area to an individual stormwater filtering system shall be less than 10 acres.

Sand and organic filtering systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with imperviousness less than 75% shall require full sedimentation pretreatment techniques.

5.5.2 *Conveyance Criteria*

If runoff is delivered by a storm drain pipe or is along the main conveyance system, the filtering practice shall be designed off-line.

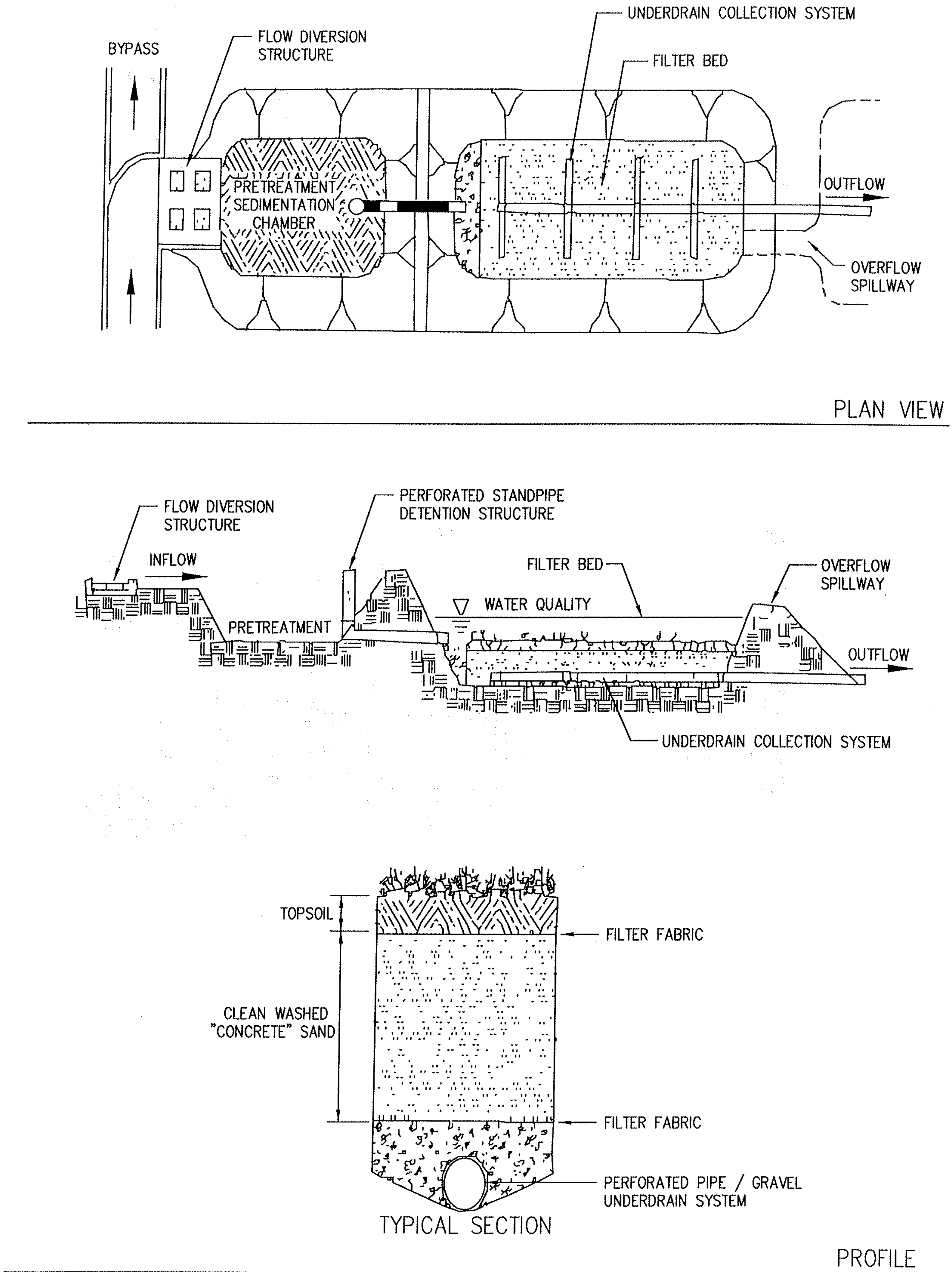


FIGURE 5-16. Surface Sand Filter

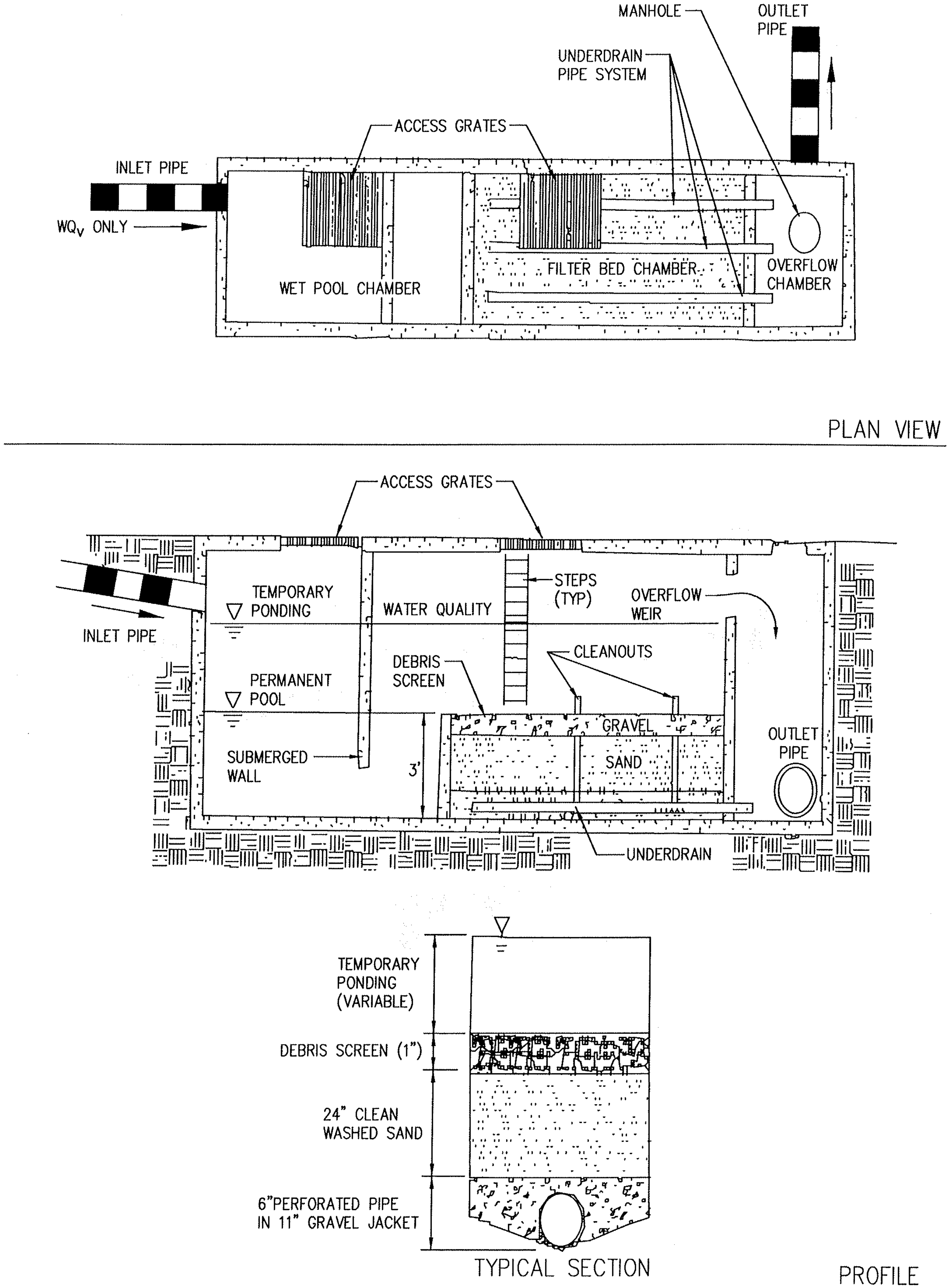


FIGURE 5-17. Underground Sand Filter

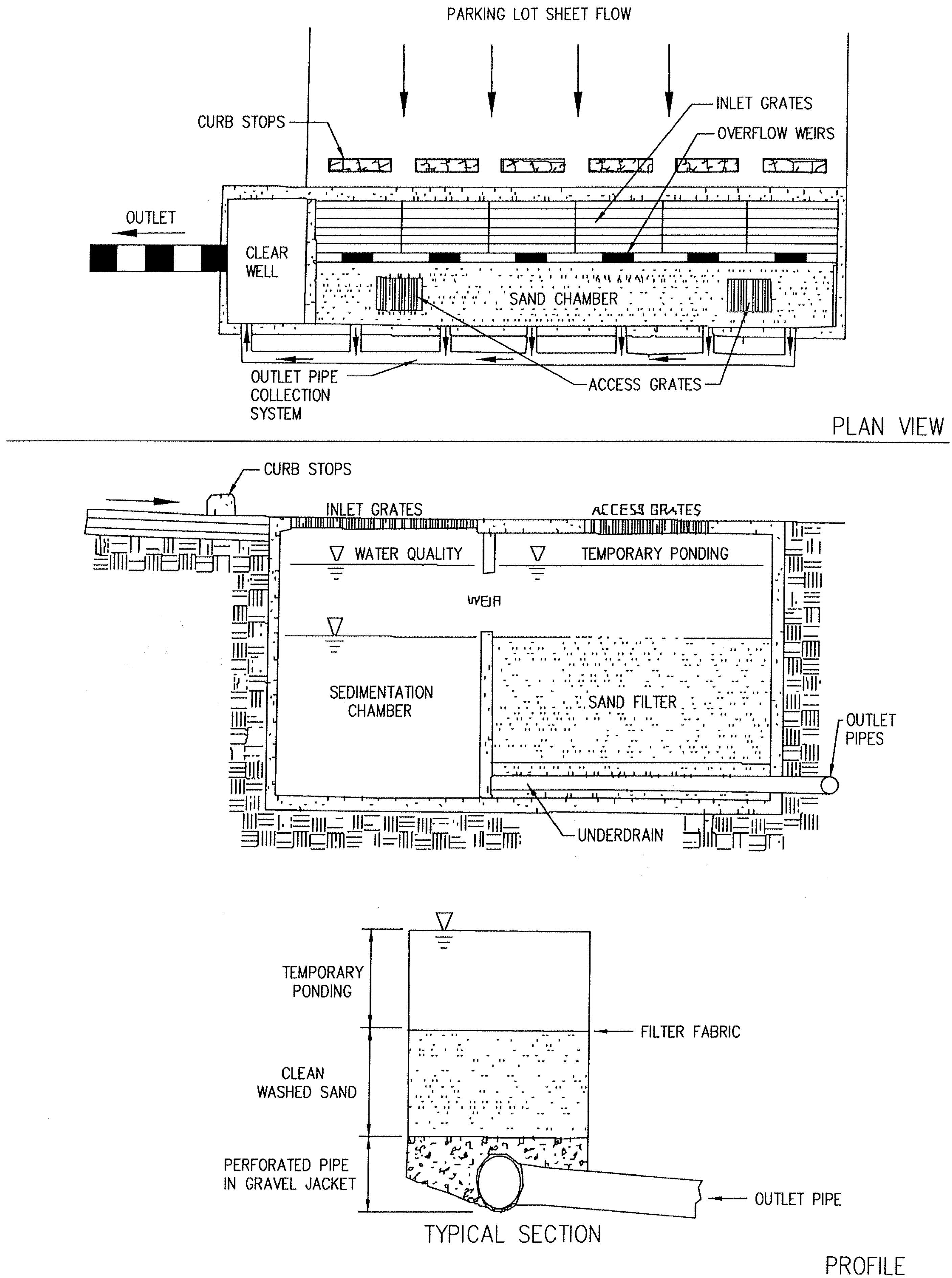


FIGURE 5–18. Perimeter Sand Filter

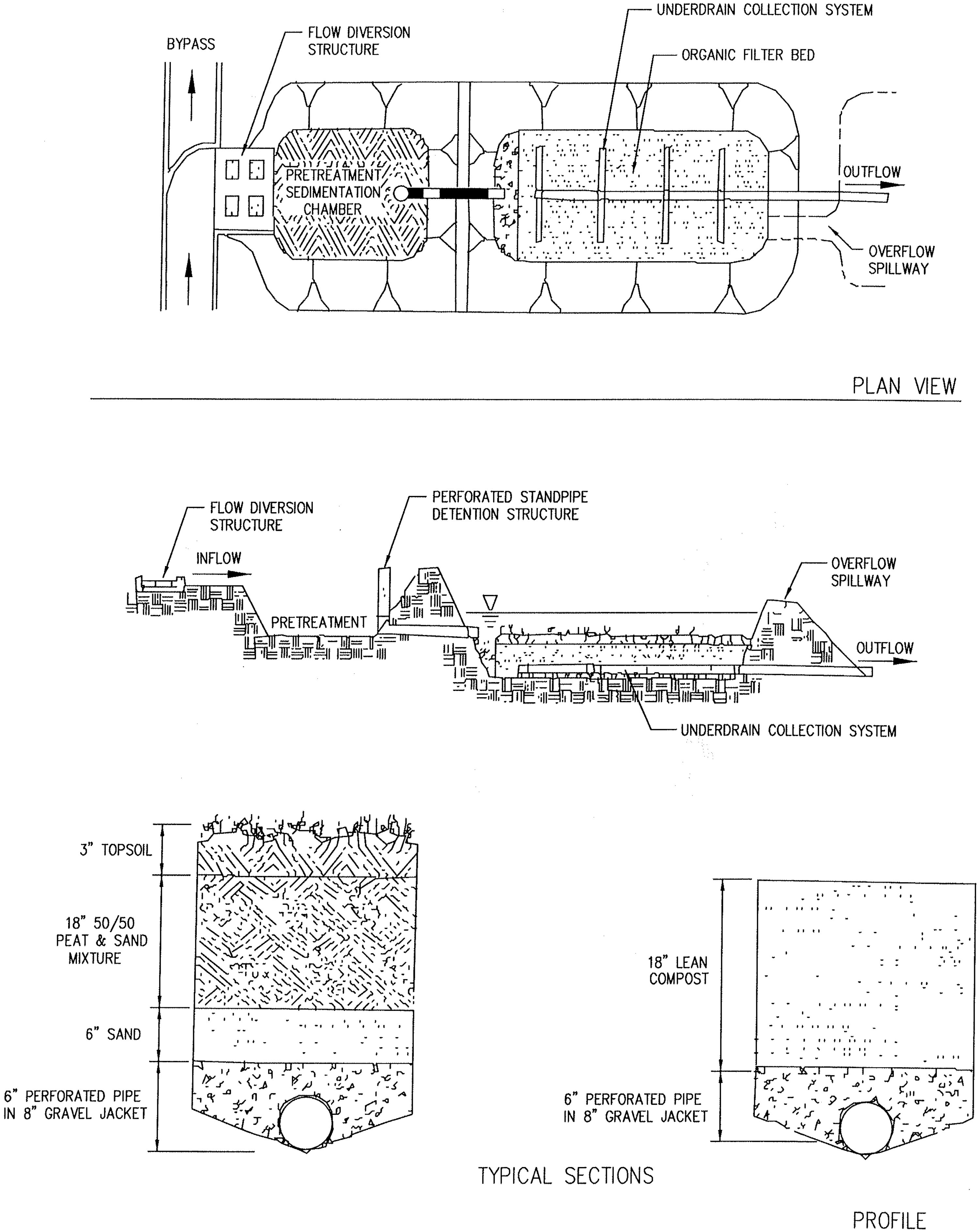


FIGURE 5–19. Organic Filter

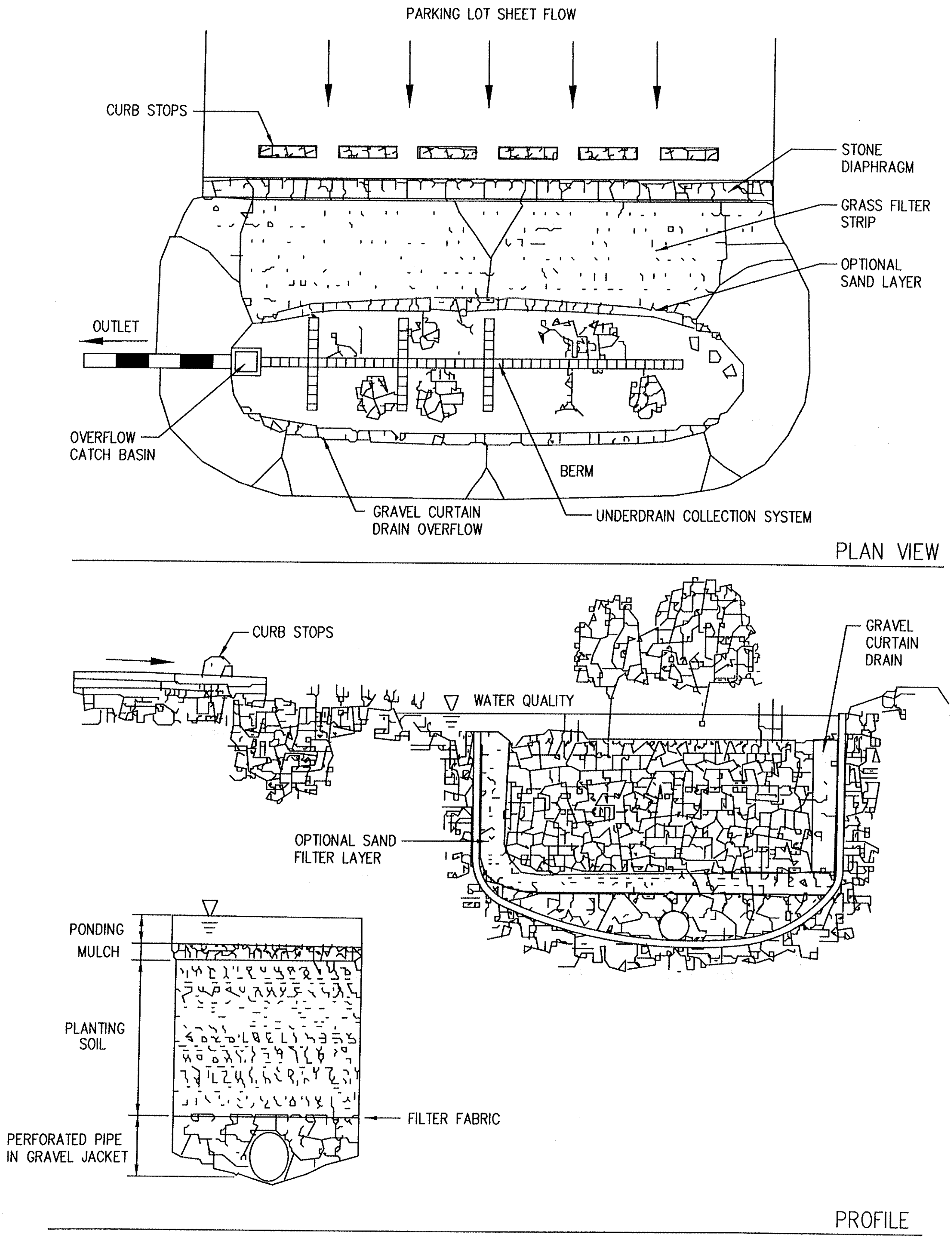


FIGURE 5-20. Bioretention

5.5.3 *Pretreatment Criteria*

Dry or wet pretreatment shall be provided prior to filter media equivalent to at least 25% of the computed WQ_v. The typical method is a sedimentation basin that has a length to width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area for sand and organic filters requiring full sedimentation for pretreatment *(9)* as follows:

The required sedimentation basin area is computed using the following equation:

$$A_s = (Q_o/W) = \text{Ln}\,(1\text{-}E) \tag{5.9}$$

Where:

A_s = Sedimentation basin surface area (ft^2)
E = sediment trap efficiency (use 90%)
W = particle settling velocity (ft/sec)
use 0.0004 ft/sec for imperviousness (I) 75%
use 0.0033 ft/sec for I > 75%
Q_o = Discharge rate from basin = (WQ_v/24 hr)

Equation reduces to:

$$A_s = (0.066)\,(WQ_v)\ ft^2 \text{ for I } 75\% \tag{5.10}$$

$$A_s = (0.0081)\,(WQ_v)\ ft^2 \text{ for I} > 75\% \tag{5.11}$$

Adequate pretreatment for bioretention systems is provided when all of the following are provided: (a) grass filter strip below a level spreader, (b) gravel diaphragm and (c) a mulch layer. In this regard, bioretention systems are fundamentally different from other filtering practices.

5.5.4 *Treatment Criteria*

The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration.

The filter media shall consist of a medium sand (meeting ASTM C-33 concrete sand). Media used for organic filters may consist of peat/sand mix or leaf compost. Peat shall be a reed-sedge hemic peat.

The filter bed shall have a minimum depth of 18" with the following exception: The perimeter filter may have a minimum filter bed depth of 12".

The filter area for sand and organic filters shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) shall be used as follows:

- Sand: 3.5 ft/day *(5)*
- Peat: 2.0 ft/day *(7)*
- Leaf compost: 8.7 ft/day *(6)*
- Bioretention Soil: 0.5 ft/day *(6)*

Bioretention systems shall consist of the following treatment components: A four foot deep planting soil bed, a surface mulch layer, and a 6" deep surface ponding area.

The required filter bed area is computed using the following equation

$$A_f = (WQ_v)\,(d_f) \,/\, [\,(k)\,(h_f + d_f)\,(t_f)] \qquad (5.12)$$

Where:

A_f = Surface area of filter bed (ft^2)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)
(1.67 days or 40 hours is maximum for sand filters, 48 hours for bioretention)

5.5.5 *Landscaping Criteria*

A dense and vigorous vegetative cover shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility.

Surface filters can have a grass cover to aid in the pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas.

Planting recommendations for bioretention facilities are as follows:

- Native plant species should be specified over non-native species.
- Vegetation should be selected based on a specified zone of hydric tolerance.
- A selection of trees with an understory of shrubs and herbaceous materials should be provided.
- Woody vegetation should not be specified at inflow locations.
- Trees should be planted primarily along the perimeter of the facility.

5.5.6 *Ownership of Stormwater Filtering Systems*

Ownership of stormwater filtering systems in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

Stormwater filtering systems may not be used in residential subdivisions.

5.5.7 *Maintenance of Stormwater Filtering Systems*

The maintenance responsibility for a stormwater filtering system shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or the permitting process.

Sediment should be cleaned out of the sedimentation chamber when it accumulates to a depth of more than six inches. Vegetation within the sedimentation chamber shall be limited to a height of 18 inches. The sediment chamber outlet devices shall be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris shall be removed as necessary.

Silt/sediment shall be removed from the filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), the top few inches of discolored material shall be removed and shall be replaced with fresh material. The removed sediments should be disposed in an acceptable manner.

A stone drop of at least six inches shall be provided at the inlet of bioretention facilities (Figure 5-19) (pea gravel diaphragm). Areas devoid of mulch should be re-mulched on an annual basis. Dead or diseased plant material shall be replaced.

Direct maintenance access shall be provided to the pretreatment area and the filter bed.

5.6 DESIGN CRITERIA – OPEN CHANNEL SYSTEMS

Open channel systems are vegetated open channels that are explicitly designed to capture and treat the full WQ_v within dry or wet cells formed by checkdams or other means. Design variants include:

- Dry Swale (Figure 5-21)
- Wet Swale (Figure 5-22)
- Grass Channels (Figure 5-23)

Dry swales and grass channels may be used in residential, private, commercial, and industrial subdivisions and developments to meet the WQ_v requirement. Wet swales may only be used in private, commercial, and industrial subdivisions and developments. Open channel systems shall not be designed to provide the detention requirement. Open channel systems shall be combined with a separate facility to provide detention.

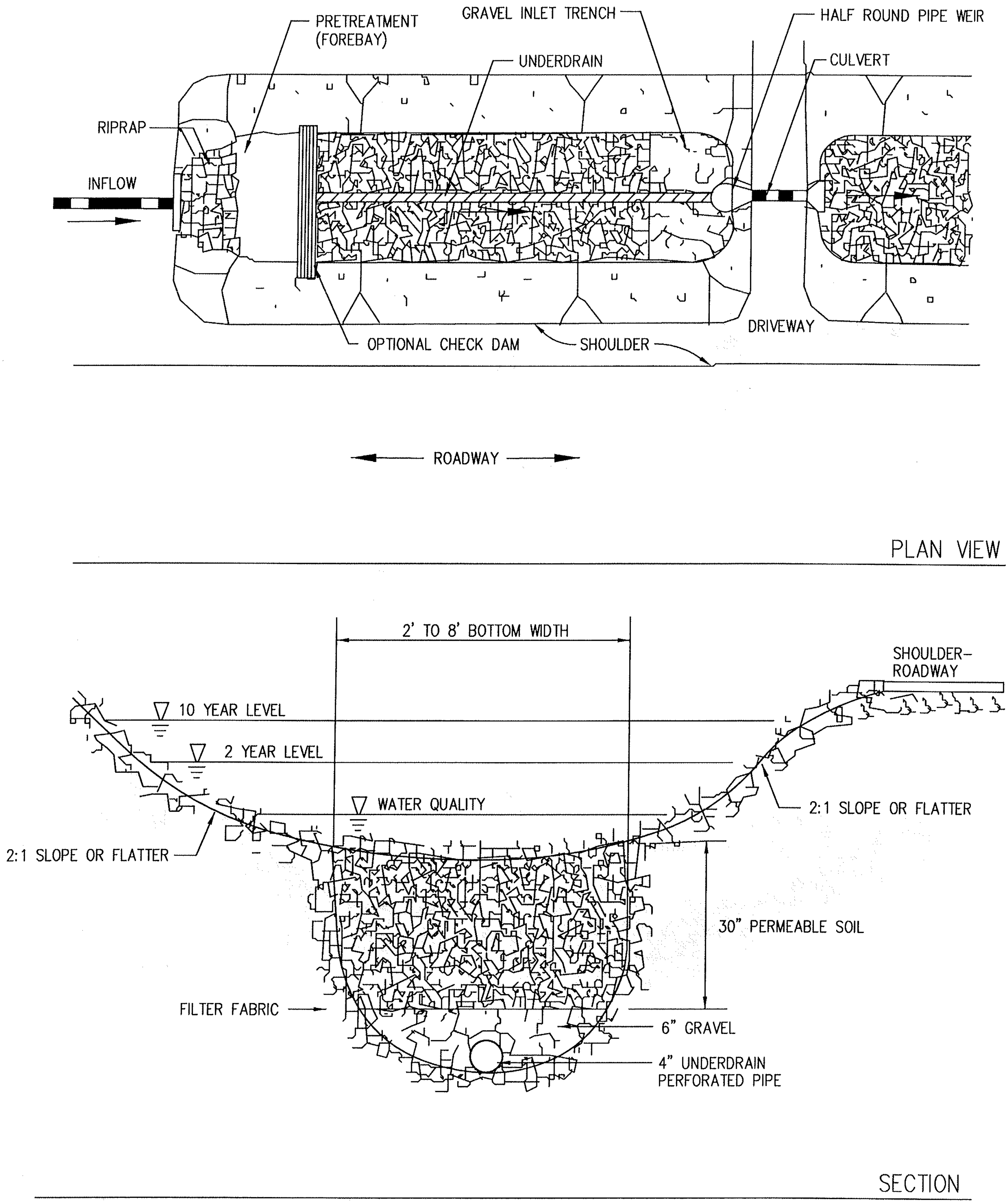


FIGURE 5-21. Dry Swale

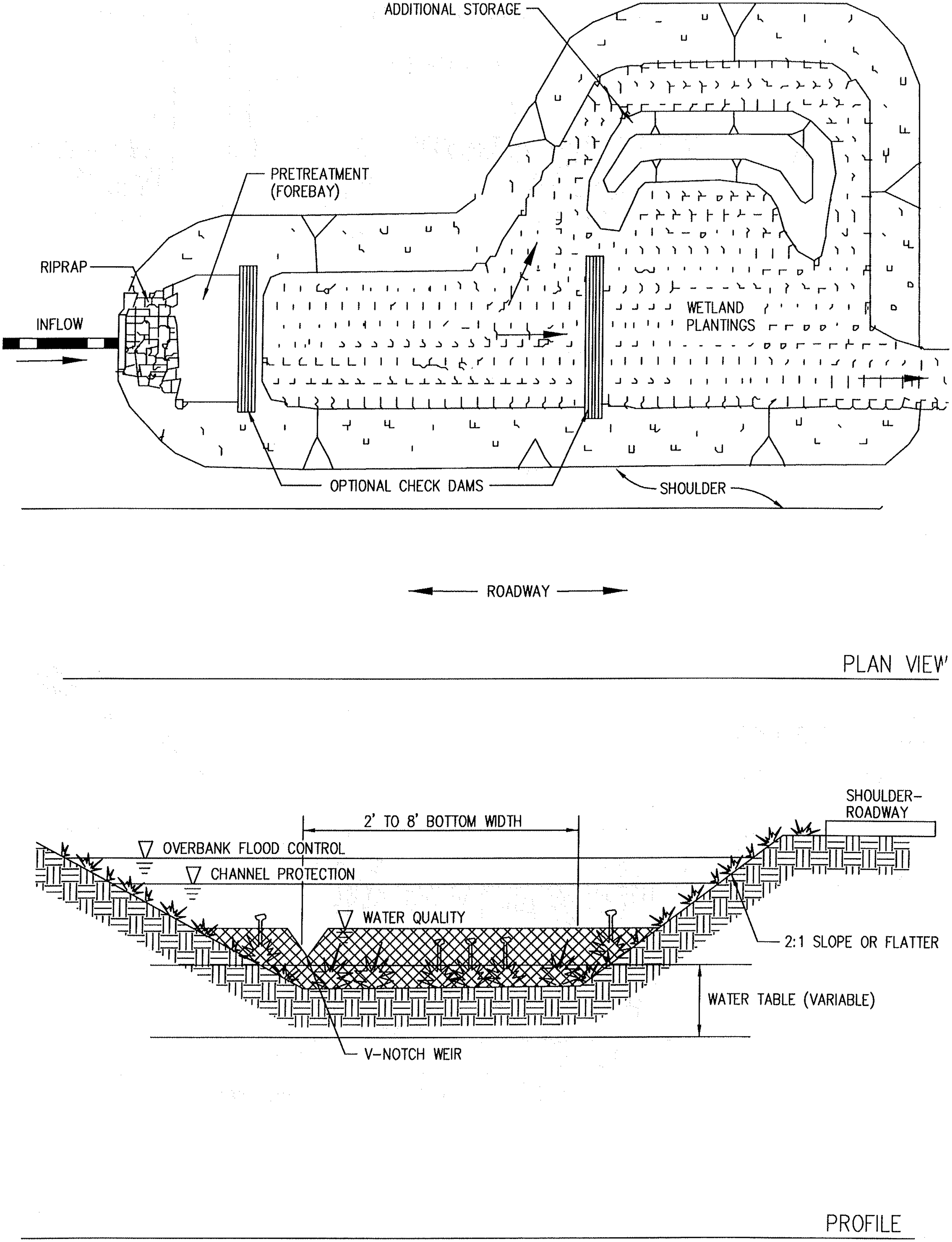


FIGURE 5-22. Wet Swale

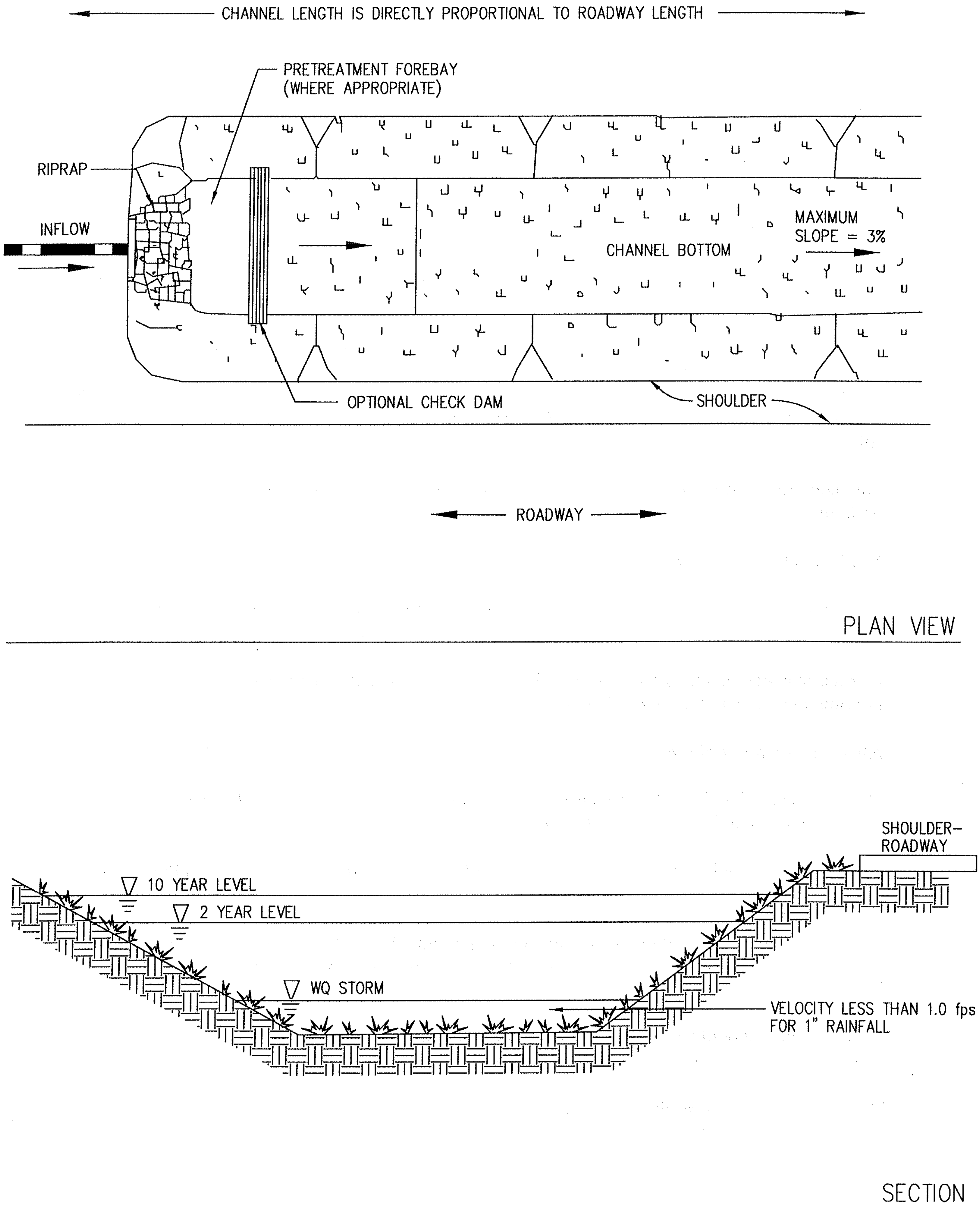


FIGURE 5-23. Grass Channels

5.6.2 *Conveyance Criteria*

The peak velocity for the 2 year storm must be non-erosive.

Open channels shall be designed to safely convey the ten year storm with a minimum of one (1.0') foot of freeboard.

Channels shall be designed with moderate side slopes for most conditions. Side slopes shall not be steeper than 4:1.

The maximum allowable temporary ponding time within a channel shall be less than 48 hours.

Open channel systems which directly receive runoff from impervious surfaces shall have a 6 inch drop onto a protected shelf (pea gravel diaphragm) to minimize the clogging potential of the inlet.

An underdrain system shall be provided for the dry swale to ensure a maximum ponding time of 48 hours.

5.6.3 *Pretreatment Criteria*

Pretreatment of 0.1 inch of runoff per impervious acre storage shall be provided. This storage is usually obtained by providing checkdams at pipe inlets and/or driveway crossings.

A pea gravel diaphragm and gentle side slopes shall be provided along the top of channels to provide pretreatment for lateral sheet flows.

5.6.4 *Treatment Criteria*

Dry and wet swales should be designed to temporarily store the WQ_v within the facility to be released over a maximum 48 hour duration.

Open channels should have a bottom width no wider than 8 feet to avoid potential gullying and channel braiding.

Dry and wet swales should maintain a maximum ponding depth of one foot at the "mid-point" of the channel, and a maximum depth of 18" at the end point of the channel (for storage of the WQ_v).

Grass channels should be designed to retain the water quality volume in the practice for a minimum of 10 minutes, with no greater than a 1.0 fps velocity.

Please note that the grass channel design is the only practice with a "rate-based" design. The designer determines the peak flow rate from the water quality storm event, and then uses

Manning's equation to ensure that the velocity required to retain flow can be achieved with the channel's cross section and slope.

5.6.5 *Landscaping Criteria*

Wet swales shall not be used for residential developments as they can create potential nuisance or mosquito breeding conditions.

Landscape design shall specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel.

5.6.6 *Ownership of Open Channel Systems*

Ownership of dry swales and grass channels in residential subdivisions accepted by the City shall be vested in the City of Fort Smith with the filing of the final plat. The Developer shall warrant the operation of the drainage system for 2 years after acceptance by the City by a Maintenance Bond provided by the Developer's Contractor or the Developer. The bond shall be required to be extended until 2 years after all phases of the subdivision or development that substantially drain to the dry swale or grass channel are completed.

Ownership of dry swales, grass channels, and wet swales in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

Wet swales may not be used in residential subdivisions.

5.6.7 *Maintenance of Open Channel Systems*

When ownership of an open channel system is not vested in the City of Fort Smith, the maintenance responsibility for the system shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or the permitting process.

Open channel systems and grass filter strips should be mowed as required during the growing season to maintain grass heights in the 4 to 6 inches range. Wet swales, employing wetland vegetation, do not require frequent mowing of the channel.

Sediment build-up within the bottom of the channel or filter strip should be removed when 25% of the original WQ_v volume has been exceeded.

5.7 DESIGN CRITERIA – SUBSTANDARD STP'S

Substandard STP's are not considered "stand alone" practices for stormwater treatment, and therefore, the acceptable STP's listed above must be considered first. However, substandard STP's may be used as pretreatment for one of the acceptable STP methodologies listed previously.

Site difficulties may prevent the use of acceptable STP's for treatment, especially with redevelopment projects. When site difficulties prevent the use of the acceptable STP's, combinations of substandard STP's may be utilized to form a "treatment train." This "treatment train" must be able to remove at least 80% of the TSS. Where appropriate, data must be submitted from the manufacturers of substandard STP's documenting the performance capabilities of the structures.

5.7.1 *Dry Extended Detention Ponds*

All of the pond criteria presented in 5.1 GENERAL and 5.2 DESIGN CRITERIA – STORMWATER PONDS also apply to the design of dry extended detention ponds.

5.7.2 *Deep Sump Catch Basins*

The sump shall be no shallower than 24 inches below the invert of the outlet pipe. The deep sump catch basin immediately upstream of the storm drain outfall must also have a hood inside the basin attached to the outlet.

5.7.3 *Other Substandard STP's*

Other substandard STP's shall be designed according to current engineering practice and according to the manufacturers' recommendations, as applicable. All accompanying data and calculations documenting reasonableness of design shall be submitted to the Engineering Department for review and approval.

5.7.4 *Ownership of Substandard STP's*

5.7.4.1 Ownership of Dry Extended Detention Ponds and Deep Sump Catch Basins

Ownership of dry extended detention ponds and deep sump catch basins in residential subdivisions accepted by the City shall be vested in the City of Fort Smith with the filing of the final plat. The Developer shall warrant the operation of the drainage system for 2 years after acceptance by the City by a Maintenance Bond provided by the Developer's Contractor or the Developer. The bond shall be required to be extended until 2 years after all phases of the subdivision or development that substantially drain to the dry extended detention pond or deep sump catch basin are completed.

Ownership of dry extended detention ponds and deep sump catch basins in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

5.7.4.2 Ownership of Other Substandard STP's

Public ownership of other substandard STP's within residential subdivisions shall be considered on a "case by case" basis by the Engineering Department. If approved, ownership shall be vested in the City of Fort Smith with the filing of the final plat. The Developer shall warrant the operation of the drainage system for 2 years after acceptance by the City by a Maintenance Bond provided by the Developer's Contractor or the Developer. The bond shall be required to be extended until 2 years after all phases of the subdivision or development that substantially drain to the STP are completed. If an STP is not approved for public ownership, it may not be used in a residential subdivision.

Ownership of other substandard STP's in commercial, industrial, private subdivisions, and non-residential areas shall be vested in the property owner.

5.7.5 *Maintenance of Substandard STP's*

5.7.5.1 Maintenance of Dry Extended Detention Basins

Dry extended detention basins shall be required to meet all the maintenance requirements found in Section 5.9.4 *Maintenance of Stormwater Ponds.*

5.7.5.2 Maintenance of Other Substandard STP's

When ownership of a substandard STP is not vested in the City of Fort Smith, the maintenance responsibility for the STP shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval or the permitting process.

Maintenance requirements for substandard STP's shall be in accordance with manufacturer's recommendations or specifications established by design engineer if the manufacturer's recommendations are unavailable.

5.8 STP SCREENING MATRICES

This section presents matrices that can be used as a screening process for selecting the best STP or group of STPs for a development site. The matrices presented can be used to screen practices in a step-wise fashion. Screening factors include:

- Land Use
- Stormwater Management Capability
- Pollutant Removal

5.8.1 *Land Use*

This matrix (see Figure 5-24) allows the designer to make an initial screen of practices most appropriate for a given land use.

Rural. This column identifies STPs that are best suited to treat runoff in rural or very low density areas.

Residential. This column identifies the best treatment options in medium to high density residential developments.

Roads and Highways. This column identifies the best practices to treat runoff from major roadways and highway systems.

Commercial Development. This column identifies practices that are suitable for new commercial development

Hotspot Land Uses. This last column examines the capability of an STP to treat runoff from designated hotspots. An STP that receives hotspot runoff may have design restrictions, as noted.

Ultra-Urban Sites. This column identifies STPs that work well in the ultra-urban environment, where space is limited and original soils have been disturbed. These STPs are frequently used at redevelopment sites.

5.8.2 *Stormwater Management Capability*

This matrix (see Figure 5-25) examines the capability of each STP option to meet stormwater management criteria. It shows whether an STP can meet requirements for:

Water Quality. The matrix tells whether each practice can be used to provide water quality treatment effectively. For more detail, consult the Pollutant Removal matrix in section 5.8.3.

Recharge. The matrix indicates whether each practice can provide groundwater recharge, however, it should be noted that groundwater recharge is not a requirement.

Channel Protection. The matrix indicates whether the STP can typically provide channel protection storage, however, it should be noted that channel protection is not a requirement.

Quantity Control The matrix shows whether an STP can typically meet the overbank flooding criteria for the site. Again, the finding that a particular STP cannot meet the requirement does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater detention pond).

FIGURE 5-24. STP Selection Matrix, Land Use.

STP GROUP	STP DESIGN	Rural	Residential	Roads and Highways	Commercial / High Density	Hotspots	Ultra Urban
Pond	Micropool ED	○	○	○	◗	①	●
	Wet Pond	○	○	○	◗	①	●
	Wet ED Pond	○	○	○	◗	①	●
	Multiple Pond	○	○	◗	◗	①	●
	Pocket Pond	○	◗	○	◗	●	●
Wetland	Shallow Marsh	○	○	◗	◗	①	●
	ED Wetland	○	○	◗	◗	①	●
	Pond/Wetland	○	○	●	◗	①	●
	Pocket Marsh	○	◗	○	◗	●	●
Infiltration	Infiltration Trench	◗	◗	○	○	●	◗
	Shallow T-Basin	◗	◗	◗	◗	●	◗
Filters	Surface Sand	●	◗	○	○	②	○
	Underground SF	●	●	◗	○	○	○
	Perimeter SF	●	●	◗	○	○	○
	Organic SF	●	◗	○	○	②	○
	Pocket Sand Filter	●	◗	○	○	②	○
	Bioretention	◗	◗	○	○	②	○
Open Channels	Dry Swale	○	◗	○	◗	②	◗
	Wet Swale	○	●	○	●	●	●
	Grass Channel	○	◗	○	◗	●	◗

○ Yes. Good option in most cases.

◗ Depends. Suitable under certain conditions, or may be used to treat a portion at the site.

● No. Seldom or never suitable.

① Acceptable option, but may require a pond liner to reduce risk of groundwater contamination.

② Acceptable option, if not designed as an exfilter.

Note: Infiltration practices, filtering practices, and wet swales may not be used in residential subdivsions or developments.

FIGURE 5-25. STP Selection Matrix, Stormwater Management Capability.

STP GROUP	STP DESIGN	WATER QUALITY?	RECHARGE?	CHANNEL PROTECTION?	FLOOD CONTROL?
Pond	Micropool ED	○	●	○	○
	Wet Pond	○	●	○	○
	Wet ED Pond	○	●	○	○
	Multiple Pond	○	●	○	○
	Pocket Pond	○	●	○	○
Wetland	Shallow Marsh	○	●	○	○
	ED Wetland	○	●	○	○
	Pond/Wetland	○	●	○	○
	Pocket Marsh	○	●	○	❷
Infiltration	Infiltration Trench	○	○	❷	❸
	Shallow I-Basin	○	○	❷	❸
Filters	Surface Sand	○	❶	❷	●
	Underground SF	○	●	●	●
	Perimeter SF	○	●	●	●
	Organic SF	○	❶	●	●
	Pocket Sand Filter	○	❶	●	●
	Bioretention	○	❶	❷	●
Open Channels	Dry Swale	○	❶	●	●
	Wet Swale	○	●	●	●
	Grass Channel	❷	❷	●	●

○	Practice generally meets this stormwater management goal.
●	Practice can almost never be used to meet this goal.
❶	Provides recharge only if designed as an exfilter system.
❷	Practice may partially meet this goal, or under specific site and design conditions.
❸	Can be used to meet flood control in rare conditions, with very cobbly or highly infiltrative soils.

Note: Only stormwater ponds and wetlands may be used in residential subdivisions or developments for flood control. Only stormwater ponds, wetlands, dry swales, and grass channels may be used in residential subdivisions or developments for water quality.

5.8.3 *Pollutant Removal*

This matrix (see Table 5-2) examines the capability of each STP option to remove specific pollutants from stormwater runoff. The matrix includes data for:

- Total Suspended Solids
- Total Phosphorous
- Total Nitrogen
- Metals
- Bacteria

TABLE 5-2. STP Selection Matrix, Pollutant Removal Efficiencies.

STP Selection Matrix. Pollutant Removal (Acceptable STP's)					
STP Group	**TSS**	**TP**	**TN**	**Metals[1]**	**Bacteria**
Ponds	80	51	33	62	70
Wetlands	76	49	30	42	78[2]
Filters[3]	86	59	38	69	37[2]
Infiltration	95[2]	70	51	99[2]	N/A
Open Channels[4]	81	34[2]	84[2,5]	61	-25[2]
(Sub-Standard STP's)					
STP Group	**TSS**	**TP**	**TN**	**Metals[1]**	**Bacteria**
Dry Extended Detention Ponds	61	19	31	26-54	N/A
Deep Sump Catch Basins	32	N/A	N/A	N/A	N/A
Water Quality Inlets[7]	35	5	20	5	N/A
Hydrodynamic Structures[7]	21	17	5[6]	17	N/A
Filter Strips (75 ft width)	54	-25	-27[6]	47	N/A
Filter Strips (150 ft width)	84	40	20[6]	55	N/A

1: Average of zinc and copper. Zinc only for infiltration and sub-standard STP's.
2: Based on fewer than five data points.
3: Excludes vertical sand filters and filter strips.
4: Highest removal rates for dry swales

5: No data available for grass channels
6: Nitrate + Nitrite
7: Percentages will vary. Refer to manufacturer for specific removal percentages.
N/A: Not applicable. Data not available

5.9 STORMWATER CREDITS

The purpose of the stormwater credit system is to provide incentive to developers, engineers, and builders to implement better site design and locate new development in a manner that causes less impact to aquatic resources. By taking advantage of the credit system, developers and builders can reduce the stormwater management quality requirements. The credit system directly translates into cost savings to the developer by reducing the water quality volume that has to be captured and treated.

This section presents two broad types of credits: Site Design Credits and Watershed Credits. Site design credits act as incentives to encourage *Better Site Design* techniques by reducing required water quality volumes on site. Watershed credits are reductions or exemptions from stormwater management requirements to support watershed goals such as redevelopment or watershed zoning.

5.9.1 *Site Design Credits*

Site design credits allow developers to reduce or eliminate requirements for *Water Quality* in exchange for implementation of these non-structural site design elements. The credits are calculated as volumes that are based on the fraction of the total site area or site impervious area affected by the credit.

Specific design credits detailed in this section include the following:

- Conservation of Natural Areas
- Reforestation
- Rooftop Disconnection
- Non-Rooftop Disconnection
- Green Rooftops

5.9.1.1 Conservation of Natural Areas

This stormwater credit rewards protection of natural vegetation or critical resource areas on site. This credit may be given when natural areas are conserved at development sites, thereby retaining their pre development hydrologic and water quality characteristics. Examples of natural area conservation areas include:

- forest retention areas
- jurisdictional wetlands

- other lands in protective easement (floodplains, open space, steep slopes)

Under the credit, a designer can subtract conservation areas from total site area when computing the water quality volume.

The credit for the water quality volume can be based on the site area in natural conservation, such that:

$$C_{WQ} = (A_{NA}/A)(WQ_v) \tag{5.13}$$

Where:

C_{WQ} = Natural Area Credit for Water Quality (ac-ft)
A_{NA} = Natural Conservation Area (acres)
A = Total Site Area (acres)
WQ_v = Original Water Quality Volume (ac-ft)

The water quality volume can then be reduced by the value of C_{WQ}. The example in Figure 5-26 illustrates how this credit would be applied.

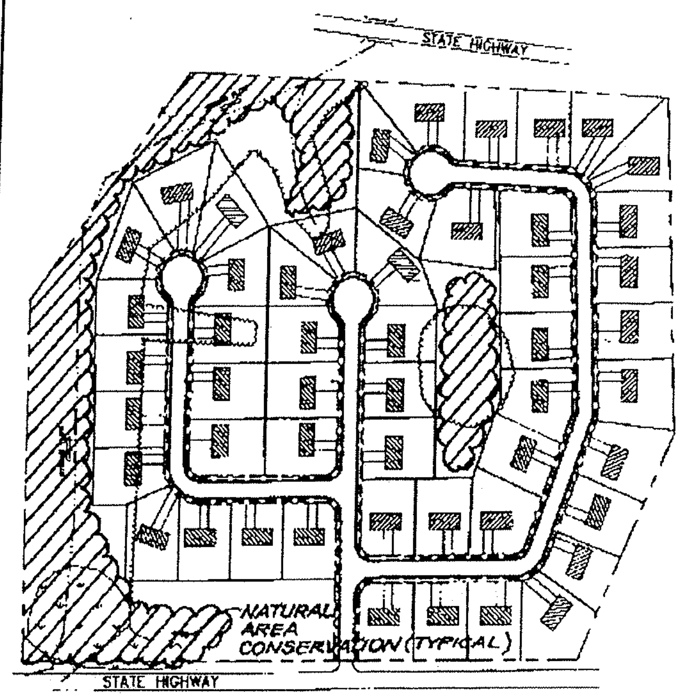
5.9.1.2 Reforestation

This credit is similar to the credit for *Conservation of Natural Areas*, except that it rewards active reforestation, rather than preservation of existing forest. This credit can apply to both *reforestation* and *afforestation.* The credit for afforestation shall be weighted higher because the afforestation implies a net increase of forest cover on the site, while reforestation only compensates for trees cleared on site.

A reforestation credit shall be applied where tree planting is used to supplement existing tree cover, or to compensate for forest cleared during development. The areas in reforestation and afforestation can be applied to water quality volumes.

In order to receive credit, the following criteria must be met:

- Tree species used for afforestation or reforestation shall be native to the City of Fort Smith, and selected from a list of approved species established by the Parks Department.
- Reforestation shall be guaranteed with a performance bond, letter of credit, or similar surety measure. The bond shall be returned after two successful growing seasons.
- Plantings shall be from nursery stock, at a minimum of 1.5" diameter at chest height.

Natural Area Conservation Credit Example	
Site Data: 51 Single Family Lots Area = 38 ac Conservation Area = 7.0 ac Original WQ_v = 1.08 ac-ft	

Computation of Stormwater Credits

C_{WQ} = (7.0 / 38)(1.08 ac-ft) = 0.20 ac-ft

WQ_v = 1.08 ac-ft – 0.20 ac-ft = 0.88 ac-ft

FIGURE 5-26. Example, Natural Area Conservation Credit.

The credit for the water quality volume can be expressed based on the area in reforestation and afforestation, such that:

$$C_{WQ} = (1.5A_A+0.5A_R)/A)(WQ_v) \tag{5.14}$$

Where:

C_{WQ} = Reforestation Credit for Water Quality (ac-ft)
A_A = Afforestation Area (acres)
A_R = Reforestation Area (acres)
A = Total Site Area (acres)
WQ_v = Original Water Quality Volume (ac-ft)

The water quality volume can then be reduced by the value of C_{WQ}. The example in Figure 5-27 illustrates how this credit would be applied.

5.9.1.3 Rooftop Disconnection

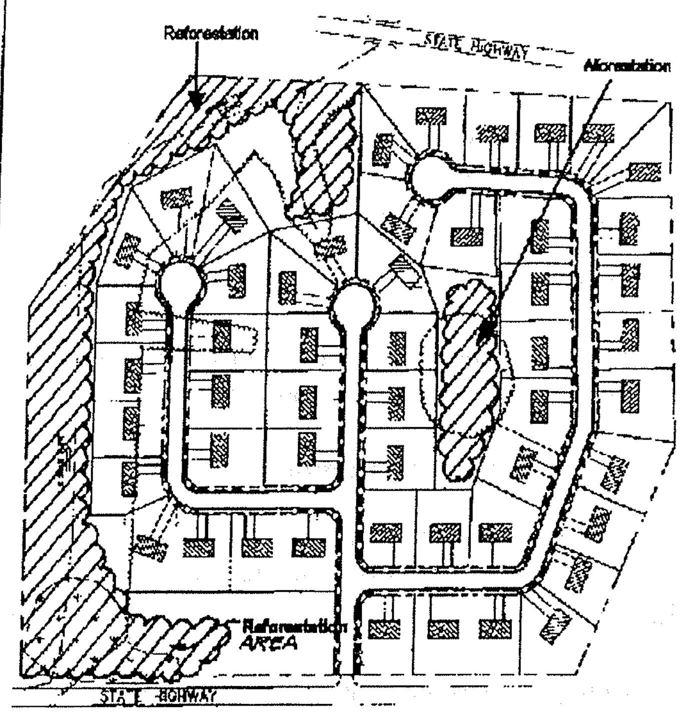
This credit can be applied to encourage disconnection of rooftops, thus promoting overland treatment of these surfaces. Credits can be applied to water quality requirements. In order to receive the credit, disconnections must meet the following criteria:

- The rooftop cannot be a designated hotspot.
- Disconnection must ensure no basement seepage.
- The contributing length of rooftop to a discharge location shall be 75 feet or less.
- The rooftop contributing area shall be no more than 1,000 sq. feet per disconnection.
- The length of the "disconnection" shall be equal to or greater than the contributing rooftop length.
- Disconnections will only be credited for residential lot sizes greater than 6000 sq. ft.
- The entire vegetative "disconnection" shall be on a slope less than or equal to 3.0%.
- The disconnection must drain continuously through a vegetated channel, swale, or through a filter strip to the property line or STP.
- Downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections."
- Disconnections are encouraged on relatively permeable soils (HSGs A and B) without soil testing.
- In less permeable soils (HSGs C and D), the water table and permeability shall be tested by a geotechnical engineer to determine if a spreading device is needed to provide sheetflow over grass surfaces. In some cases, dry wells, french drains or other temporary underground storage devices may be needed to compensate for a poor infiltration capability.
- For those rooftops draining directly to a stream buffer, one can only use either the rooftop disconnection credit or the stream buffer credit, not both.

Reforestation Credit Example

Site Data: 51 Single Family Lots
Area = 38 ac
Reforestation Area = 5.0 ac
Afforestation Area = 2.0 ac
Impervious Area = 13.8 ac

Original WQ_v = 1.08 ac-ft



Computation of Stormwater Credits

C_{WQ} = [((1.5 x 2.0 ac) + (0.5 x 5.0 ac)) / 38ac] x 1.08 ac-ft = 0.16 ac-ft

WQ_v = 1.08 ac-ft – 0.16 ac-ft = 0.92 ac-ft

FIGURE 5-27. Example, Reforestation Credit.

The water quality credit can be calculated with the following equation:

$$C = (A_{DR}/A_I)WQ_v \tag{5.15}$$

Where:

C = Rooftop Disconnection Credit (ac-ft)
A_{DR} = Disconnected Roof Area (acres)
A_I = Site Impervious Area (acres)
WQ_v = Original Water Quality Volume.

The water quality volume would both be reduced by the credit (C). The example in Figure 5-28 illustrates how this credit would be applied.

FIGURE 5-28. Example, Rooftop Disconnection Credit.

Rooftop Disconnection Credit Example

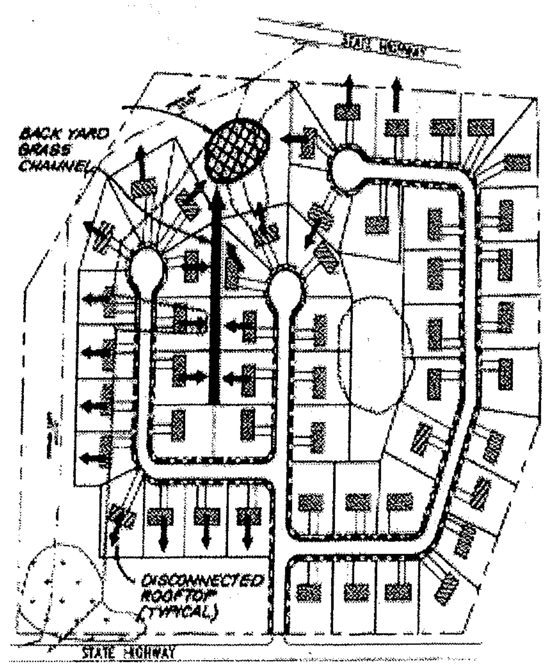
Site Data: 51 Single Family Lots
Area = 38 ac
Original Impervious Area = 13.80 ac

\# of Disconnected Rooftops = 22
Original WQ_v = 1.08 ac-ft

22 Lots Disconnected
(2500 sq ft each)

Net impervious area reduction

(22)(2500) / (43560) = 1.3 ac



Computation of Stormwater Credits

$C = (1.3 / 13.8)(1.08 \text{ ac-ft}) = 0.10 \text{ ac-ft}$

$WQ_v = 1.08 \text{ ac-ft} - 0.10 \text{ ac-ft} = 0.98 \text{ ac-ft}$

5.9.1.4 Non-Rooftop Disconnection

This credit is applied to credit disconnection of other impervious surfaces by encouraging drainage to overland treatment such as swales or filter strips. In order to receive the credit, disconnections must meet the following criteria:

- The maximum contributing impervious flow path length shall be 75 feet.
- Runoff cannot come from a designated hotspot.
- The disconnection must drain continuously through a vegetated channel, swale, or filter strip to the property line or STP.
- The length of the "disconnection" must be equal to or greater than the contributing length.
- The entire vegetative "disconnection" shall be on a slope less than or equal to 3.0%.
- The surface imperviousness area to any one discharge location cannot exceed 1,000 ft^2.
- Disconnections discharging over relatively permeable soils (HSGs A and B) do not require geotechnical testing.
- If the site has less impermeable soils (HSGs C and D), testing by a geotechnical engineer is needed to determine if a spreading device, such as a french drain, gravel trench or other temporary storage device is needed to compensate for poor infiltration capability.

The water quality credit can be calculated with the following equation:

$$C = (A_D/A_I)WQ_v \qquad (5.16)$$

Where:

C = Non-Rooftop Credit (ac-ft)
A_D = Disconnected Impervious Area (acres)
A = Total site area (acres)
A_I = Site Impervious Area (acres)
WQ_v = Original Water Quality Volume.

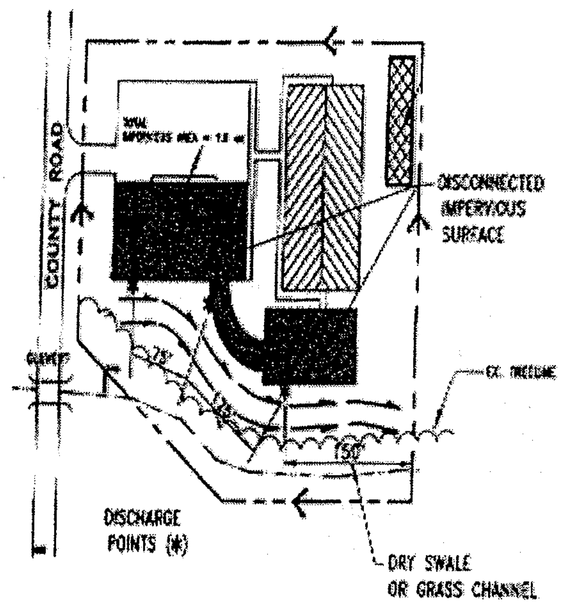
The water quality volume can then be reduced by the credit (C). The example in Figure 5-29 how this credit would be applied.

Non-Rooftop Disconnection Credit Example

Site Data: Community Center
Area = 3.0 ac
Original Impervious
Area = 1.9 ac = 63.3%

Original WQ_v = 6,752 ft^3

0.8 ac of surface imperviousness disconnected



Computation of Stormwater Credits

$C = (0.8 / 1.9)(6{,}752\ ft^3) = 2{,}843\ ft^3$

$WQ_v = 6{,}752\ ft^3 - 2{,}843\ ft^3 = 3{,}909\ ft^3$

FIGURE 5-29. Example, Non-Rooftop Disconnection Credit.

5.9.1.5 Green Rooftop Credit

The term "green rooftops" refers to a few practices that detain and treat stormwater runoff on rooftops using vegetation on the roof surface. Several different options exist, including variations on the type of vegetation used, and the specific design of the green roof. The criteria presented below are adapted from the Portland Stormwater Manual criteria for the Eco-Roof. In order to receive the credit, green rooftops must meet the following criteria:

- The system shall include a 6" soil bed, with a silt loam texture.
- The soil bed shall be underlain with a 2" gravel layer, and these two layers shall be separated by a layer of filter fabric.
- An impermeable layer shall be placed between the rooftop and the gravel layer.
- The roof shall have a maximum slope of 25%
- The roof shall be designed to hold an additional 25 lbs/sf, beyond minimum regional design criteria
- Vegetation shall be established within two growing seasons.
- Vegetation should require minimal fertilization, watering and pesticides.
- A 2" mulch layer shall be immediately placed above the soil layer to prevent erosion.
- The vegetation and mulch layer shall be maintained at least quarterly, removing dead vegetation and eroded mulch.
- If the rooftop is used as an amenity (e.g., a rooftop sitting area) as well as to detain stormwater, credit shall only be applied to pervious sections of the rooftop.
- The credit shall only apply for businesses where owners sign a maintenance agreement.

The water quality credit can be calculated with the following equation:

$$C = (A_{GR}/A_I)WQ_v \tag{5.17}$$

Where:

C = Green Rooftop Credit (ac-ft)
A_{GR} = Green Rooftops (acres)
A_I = Site Impervious Area (acres)
WQ_v = Original Water Quality Volume (ac-ft)

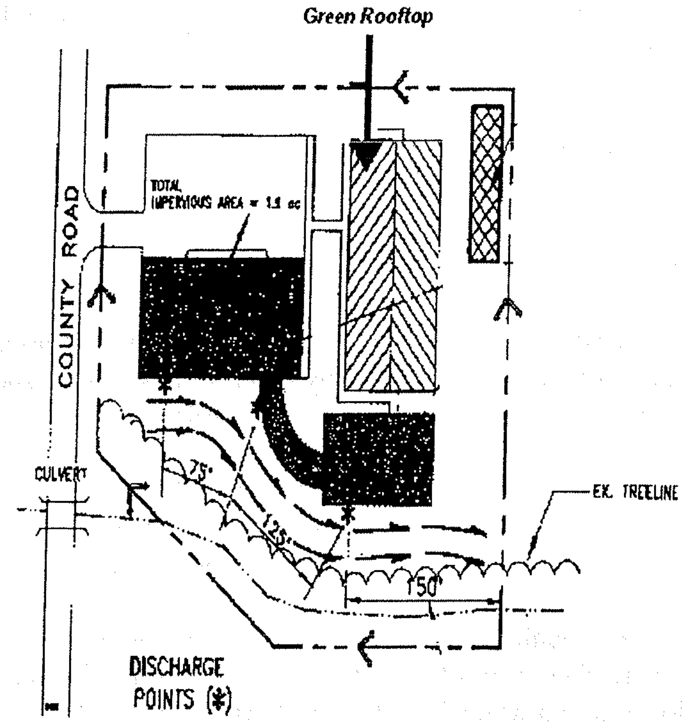
The water quality volume is then reduced by the credit, C. The example in Figure 5-30 illustrates how this credit would be applied.

Green Rooftop Credit Example

Site Data: Community Center
Area = 3.0 ac
Original Impervious
Area = 1.9 ac = 63.3%

Original $WQ_v = 6{,}752 \text{ ft}^3$

0.5 ac of green rooftops



Computation of Stormwater Credits

$C = (0.5 / 1.9)(6{,}752 \text{ ft}^3) = 1{,}777 \text{ ft}^3$

$WQ_v = 6{,}752 \text{ ft}^3 - 1{,}777 \text{ ft}^3 = 4{,}975 \text{ ft}^3$

FIGURE 5-30. Example, Green Rooftop Credit.

5.9.2 *Watershed Credits*

Watershed credits focus on the location of the development, rather than on the design of the site. They reward developers who locate in areas that result in less impact to water resources by encouraging development in already urbanized or highly degraded areas. Three watershed credits are presented in this section:

- Watershed Zoning
- Infill
- Redevelopment

5.9.2.1 Watershed Zoning

This credit reduces stormwater management requirements in developments that support a strategy of *watershed zoning* by locating in subwatersheds that are designated as *non-supporting*. A watershed Zoning Credit can be awarded to developments that meet the following criteria:

- Must be located in a subwatershed with greater than 25% impervious cover
- Shall not contribute more than 5% impervious cover to the subwatershed, or to the drainage of any 2^{nd} order or larger stream.

The water quality credit received is a function of the impervious cover fraction in the subwatershed, times the water quality volume. This credit will not be given if the development is located in a watershed that discharges directly to a stream with a published Total Maximum Daily Load (TMDL). Furthermore, this credit will not be given if it is found that the development will impact a relatively high quality reach within the subwatershed.

5.9.2.2 Infill Credit

The infill credit acts as an incentive for developing infill lots, as opposed to greenfields away from existing development. Infill development results in lower infrastructure costs, fewer miles driven, and a net reduction in impervious cover creation when compared with greenfield development.

An infill credit can be applied to all sites that are built within the current sewer envelope, and are smaller than 5 acres for residential development, and 2 acres for commercial or industrial uses. Sites that meet these criteria can receive a 20% water quality credit. This credit will not be given if the development is located in a watershed that discharges directly to a stream with a published TMDL. Furthermore, this credit will not be given if it is found that the development will impact a relatively high quality reach within the subwatershed.

5.9.2.3 Redevelopment Credit

The redevelopment credit encourages development on sites that have previous commercial, industrial, or residential land use. The credit allows reduction in required treatment and management volumes, depending on the existing conditions at the site. For redevelopment projects, treatment is only required for the additional stormwater generated on site.

The redevelopment credit may be awarded for all redevelopment sites. The water quality credit is based on pre-developed impervious cover. The credit can be expressed as:

$C = I_P WQ_v$
Where:
C = Credit (ac-ft)
I_P = Pre-Developed Impervious Cover

This credit can then be subtracted from the water quality volume.

Redevelopment Credit Example
Consider a site with a pre-developed impervious cover of 25% and a water quality volume of 10,000 ft^3.
Redevelopment Credit Calculation $C = (10,000\ ft^3)(25\%) = 2,500\ ft^3$ $WQ_v = 10,000\ ft^3 - 2,500\ ft^3 = 7,500\ ft^3$

It should be noted that stormwater treatment is not required for redevelopment projects less than one acre in size or projects where the impervious area will not be increased.

5.10 REFERENCES

(1) American Public Works Association, Kansas City Metropolitan Chapter. *Division V, Construction and Material Specifications, Section 5600 Storm Drainage Systems and Facilities.* February 2006.

(2) Arkansas Soil and Water Conservation Commission. *Title VII, Rules Governing Design and Operation of Dams.* October 1993.

(3) Brater, E. F. and H. W. King. *Handbook of Hydraulics.* 6th edition. McGraw Hill Book Company, New York, NY, 1976.

(4) Chow, V. T. *Open Channel Hydraulics.* McGraw Hill Book Company, New York, 1959.

(5) City of Austin, TX. 1988. Water Quality Management. Environmental Criteria Manual. Environmental and Conservation Services. Austin, TX.

(6) Claytor, R.A., and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection, Silver Spring, MD.

(7) Galli, F. 1990. Peat-Sand Filters: A Proposed Stormwater Management Practice for Urban Areas. Metropolitan Washington Council of Governments. Washington, DC.

(8) US Soil Conservation Service (SCS). August 1981. Technical Release No. 60, "Earth Dams and Reservoirs", as Class "C" structures.

(9) Washington State Department of Ecology (WSDE). 1992. Stormwater Management Manual for the Puget Sound Basin. Olympia, WA.

APPENDIX 5A

40 CFR 122.26(b)(14) Subpart (i) – (xi)

(Source: ADEQ)

INDUSTRIAL FACILITIES THAT MUST SUBMIT APPLICATIONS FOR STORM WATER PERMITS

40 CFR 122.26(B)(14) Subpart	Description	
(i)	Facilities subject to storm water effluent limitations guidelines, new source performance standards, or toxic pollutants effluent standards under 40 CFR, Subchapter N [except facilities which are exempt under category (xi)].	
(ii)	Facilities classified as:	
	SIC 24 (EXCEPT 2434)	Lumber and Wood Products
	SIC 26 (EXCEPT 265 and 267)	Paper and Allied Products
	SIC 28 (EXCEPT 283 and 285)	Chemicals and Allied Products
	SIC 29	Petroleum and Coal Products
	SIC 311	Leather Tanning and Finishing
	SIC 32 (except 323)	Stone, Clay and Glass Products
	SIC 33	Primary Metal Industries
	SIC 3441	Fabricated Structural Metal
	SIC 373	Ship and Boat Building and Repairing

40 CFR 122.26(B)(14) Subpart	Description
(iii)	Facilities classified as SIC 10 through 14, including active or inactive mining operations and oil and gas exploration, production, processing, or transmission facilities that discharge storm water contaminated by contact with, or that has come into contact with, any overburden, raw material, intermediate products, finished products, byproducts, or waste products located on the site of such operations. SIC 10 Metal Mining SIC 11 Anthracite Mining SIC 12 Coal Mining SIC 13 Oil and Gas Extraction SIC 14 Nonmetallic Minerals, except Fuels
(iv)	Hazardous waste treatment, storage, or disposal facilities, including those that are operating under interim status or a permit under Subtitle C of the Resource Conservation and Recovery Act (RCRA).
(v)	Landfills, land application sites, and open dumps that receive or have received any industrial wastes including those that are subject to regulation under subtitle D or RCRA.

40 CFR 122.26(B)(14) Subpart	Description
(vi)	Facilities involved in the recycling of material, including metal scrap yards, battery reclaimers, salvage yards, and automobile junkyards, including but limited to those classified as: SIC 5015 — Motor Vehicle Parts, Used SIC 5093 — Scrap and Waste Materials
(vii)	Steam electric power generating facilities, including coal-handling sites.
(viii)	Transportation facilities which have vehicle maintenance shops, equipment cleaning operations, or airport de-icing operations. Only those portions of the facility that are either involved in vehicle maintenance (including vehicle rehabilitation, mechanical repairs, fueling, and lubrication), equipment cleaning operations, or airport de-icing operations, or which are otherwise listed in another category, are included. SIC 40 — Railroad Transportation SIC 41 — Local Suburban Transit SIC 42 (except 4221-25) — Motor Freight and Warehousing SIC 43 — U.S. Postal Service SIC 44 — Water Transportation SIC 45 — Transportation by Air SIC 5171 — Petroleum Bulk Stations and Terminals

40 CFR 122.26(B)(14) Subpart	Description
(ix)	Treatment works treating domestic sewage or any other sewage sludge or wastewater treatment device or system, used in the storage, treatment, recycling, and reclamations of municipal or domestic sewage, including lands dedicated to the disposal of the sewage sludge that are located within the confines of the facility, with a design flow of 1.0 million gallons per day or more, or required to have an approved pretreatment program under 40 CFR Part 403. Not included are farm lands, domestic gardens, or lands used for sludge management where sludge is beneficially reused and which are not physically located in the confines of the facility, or areas that are in compliance with Section 405 of the Clean Water Act.
(x)	Construction activity including clearing, grading, and excavation activities except operations that result in the disturbance of less than 5 acres of total land area and those that are not part of a larger common plan of development or sale. *

40 CFR 122.26(B)(14) Subpart	Description	
(xi)	Facilities under the following SICs [which are not otherwise included in categories (ii)-(x)], including only storm water discharges where material handling equipment or activities, raw materials, intermediate products, final products, waste materials, byproducts, or industrial machinery are exposed to storm water. *	
	SIC 20	Food and Kindred Products
	SIC 21	Tobacco Products
	SIC 22	Textile Mill Products
	SIC 23	Apparel and Other Textile Products
	SIC 2434	Wood Kitchen Cabinets
	SIC 25	Furniture and Fixtures
	SIC 265	Paperboard Containers and Boxes
	SIC 267	Converted Paper and Paper Board Products (except containers and boxes)
	SIC 27	Printing and Publishing
	SIC 283	Drugs
	SIC 285	Paints, Varnishes, Lacquer, Enamels
	SIC 30	Rubber and Misc. Plastics Products
	SIC 31 (except 311)	Leather and Leather Products
	SIC 323	Products of Purchased Glass
	SIC 34 (except 3441)	Fabricated Metal Products
	SIC 35	Industrial Machinery and Equipment, except Electrical
	SIC 36	Electronic and Other Electric Equipment
	SIC 37 (except 373)	Transportation Equipment

40 CFR 122.26(B)(14) Subpart	Description	
	SIC 38	Instruments and Related Products
	SIC 39	Miscellaneous Manufacturing Industries
	SIC 4221	Farm Products Warehousing and Storage
	SIC 4222	Refrigerated Warehousing and Storage
	SIC 4225	General Warehousing and Storage

Source: Federal Register, Volume 55, Number 222, Page 48065, November 16, 1990.

* On June 11, 1992, the U.S. Court of Appeals for the Ninth Circuit remanded the exemption for construction sites of less than five acres in Category (x) and for manufacturing facilities in category (xi) which do not have materials or activities exposed to storm water to the EPA for further rulemaking. (Nos. 90-70671 & 91-70200).